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Oilfield Practice.

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The increasing depth of wells in most oilfields is calling for stronger and better drilling equipment, heavier and superior casing, and improved control arrangements as well as new methods of production. As pressure is mainly a function of depth, increased depths lead to greater gas pressures as well as more dangerous earth movements unless balancing pressures are arranged. Deep drilling in soft formations enforces the use of hydraulic systems if high speeds are sought and economy in casing is desired. The hydraulic rotary system of drilling is gradually superseding all other methods, especially as constant improvements in design and manufacture are enabling harder strata to be attacked.

Elaborate precautions are now taken in bringing deep wells into production in deep territory where high pressures must be faced Every care is taken to prevent wells flowing out of control, for once the balancing pressure of a column of liquid is partially or entirely removed, and replaced by a column of gas much difficulty may be found in regaining control. In the case of wells in soft sediments of Tertiary age, the dangers are accentuated by cavings which generally cause damage to the casing. Few deep wells in Rumania and Russia which run wild, escape casing damage or even permanent injury, therefore few producers care to risk the loss of an expensive well, however much they favour open flow as a factor in opening up an oil source and deflecting oil from neighbouring lands.

Insistence in perpetuating old-time practice to new conditions has led to many lost wells. Although those in intimate touch with oilfield operations appreciate the value of open flow, in establishing a long distance feeder system unattainable by controlled discharge, the cautious are reluctant to run the risks where such a big capital expenditure is at stake.

Under regulated flow, individual wells do not probably give the same ultimate production as by open flow, provided the casing suffers no damage, but few wells in fields of Tertiary age, where unconsolidated strata occur, escape damage under open flow

conditions and, consequently, few deep wells have probably given as much oil as might have been obtained by controlled flow.

The increasing value of gas and the light constituents of the oil are other factors which are influencing the handling of wells. As the gas present with, or dissolved in, the oil is roughly proportional to the pressure, and pressure varies approximately with depth, there is a much greater volume of gas available per barrel of oil in the deep sources than in the shallow, and its unrestricted discharge leads to a greater waste of potential energy.

Open flow leads to great loss of gas, however carefully a well may be arranged, and the oil itself suffers loss of light spirit by evaporation. As oil is usually sold to-day either by gravity or gasoline content, heavy financial losses result from the negligent handling of oils, especially those of light density.

It is now customary to arrange the wells to flow under control into separators where the gas and oil separate under pressure, the former going to gasoline extractors for treatment, the latter passing into the storage tanks.

The safe completion of these deep, high pressure wells, especially in unconsolidated strata calls for considerable care and skill, besides the employment of high-class steel fittings. Final columns of casing fitted with screens or perforated pipe are inserted through stuffing boxes with control side discharges so that in the event of a blowout the well can be throttled. Flow-pipes are likewise inserted through strong stuffing boxes designed to admit the passage of the collars. Only on the completion of all surface arrangements is a well swabbed or bailed to remove the drilling mud. Once a flow is stimulated and oil appears, the valves are closed and the discharge is led through flow nipples into the separators.

Flow nipples, beans or plugs are being increasingly used, even in Rumania and Russia, where scepticism still prevails. The size is varied to suit the conditions, but generally they range from $\frac{1}{4}$" to 1" diam. A "Xmas tree" arrangement is usually fitted at the well mouth whereby oil can be deflected by a series of valves to spare nipples so that a worn one can be replaced or a different size introduced. Usually a rate of flow is adjusted so that little sand accompanies the oil after the first few days of flow.

The flow-pipe has to be inserted to some point usually found by trial, and its depth may have to be varied from time to time. In California the ratio of casing-head to flow pressure is used to determine the most efficient rate of flow; that is, a flow which is sustained with the minimum volume of gas per barrel of oil, regardless of the immediate and temporary increase of yield possible by introducing a larger nipple and wasting more gas. Owing to many unknown variables, only by trial and error can a size of bean and rate of

flow and relative casing-head and flow-pipe pressure be fixed which will ensure prolonged flow without wasting gas, sanding up or other troubles.

The general use of flow nipples in deep wells has led to the re-introduction of the air-lift or rather its equivalent gas-lift in a modified form. Great economies have been effected by returning part of the gas to the casing head by means of compressors, thus augmenting the propellant, or to speak more correctly, the agent whereby the oil is sufficiently lightened to enable it to flow. This is merely an adaptation of the air-lift when only sufficient air or gas was introduced to continue the flow after the period of natural flow through a certain sized flow-pipe had ceased. The use of gas is preferable to air, because it is more soluble in oil, does not cause precipitation of lime from associated waters, neither does it dilute the gas nor produce explosive mixtures which would prejudice gasoline extraction processes. Unquestionably the process will find extended use and be a natural sequence to the advancing use of flow nozzles. In most Californian wells where the final casings are small it is usual to conduct the air between the casing and the flow-pipe instead of introducing two strings of pipes.

As an example of the influence of gas-lift in deep Californian wells may be instanced a typical case in the Dominguez field where the production of crude was raised from 163 to 315 barrels a day, and the gas-gasoline output rose by 23,000 gallons a day. The gravity of the oil was usually decreased by 0·50°B. to 1° B. in California.

Air-lift has been extensively used where the conditions were favourable for its use. Wells in certain Mid-Continental fields of U.S.A., as El Dorado, Oklahoma, which had high fluid levels and large potential capacity, but yielded insufficient gas to cause a natural flow, were very successfully treated with air. In other Texan and Mid-Continental fields large quantities of water were present with the oil in the limestone reservoir. In neither case could anything like the full capacity of the wells be attained in any other way than by air-lift. So successful was this method that in some cases the cost of a compressor installation was paid for within 48 hours of erection by the increased productions obtained. It was not merely a question of quickly obtaining returns, but those first equipped with air were able, under the conditions prevailing, to take out much more oil than their fair share, based on the acreage they held. Some wells in the Powell field had their yields raised from a few hundred barrels to 2000 to 3000 barrels of oil per day on the application of air-lift. Many Californian wells equipped with gas-lift had their productions raised from 140 to 150 barrels to 1000 barrels.

Extensive recent use has been made of air-lift in the Baku oil-field of Russia, where about one-third of the total production or

1,000,000 barrels per month has been raised by this method. Many wells had their outputs increased five- to ten-fold by means of air-lift.

Wells up to 5000 ft. in depth are now being satisfactorily pumped in California. The initial difficulties have been largely overcome by using long-stroke pumps which ensure a stroke of the plunger adequately compensating for the stretch of the rods. In some cases two or more pump barrels are inserted in the pump tubing, and in other cases the power needed to lift the oil has been reduced by the introduction of gas into the pump tubing at some point well above the fluid level. Of course, no pumping difficulties are experienced in the deep wells until the fluid level falls to a low point. Exceptional care is taken in the manufacture of pump barrels, and plungers and valves as at pressures approximating 2000 lbs. per sq. in., a small amount of slip not only results in high volumetric losses, but introduces conditions ideal for the formation of emulsions if water is present. Solid plungers are universally used in the deep wells and renewable liners for the barrels are also arranged. Owing to difficulties inseparable from pumping deep wells, air- and gas-lift is coming more and more into favour even in wells with a low liquid level and consequent reduced efficiency.

A perusal of American oilfield literature in which the candid and varied views of operators are expressed shows how dangerous it is to dogmatise on the subject of equipment. Although much has been claimed for the long-stroke pump in deep wells and theoretical considerations lend weight to these claims, there are other practical and less obvious reasons for their occasional failure when installed. In many cases the production of a well has diminished as a result of their installation, and breakdowns have in some instances been a factor of importance. It is thought that the quicker speed short-stroke pump really acts as an agitator more than a pump, and in the case of heavy gravity oils the agitation causes flows by heads which more than compensate for loss of stroke.

With the air- or gas-lift process inconsistencies and disappointments have likewise been met with in California and elsewhere due to failure to recognise its limitations or fully to appreciate the influence of some peculiarity in the behaviour of the well. In some instances productions could never be reached equal to those obtained by pumping due to low working level of fluid, influx of sand and other causes. One well-known Californian engineer has recently emphasised a point of view which is in entire accord with the writer's personal experiences, namely, that the introduction of a nozzle or jet at the point of air admission is quite unnecessary and it often impairs the working of an installation.

It should be appreciated that every oil well in many fields is a problem in itself and its peculiarities must be understood before the best method of handling can be determined. There is a tendency in modern days to run every new innovation to death with the result that valuable processes become generally discredited until reintroduced with more discretion at a later date.

Pumps have been widely introduced into the Russian oilfields where settled conditions have been reached, and it is said that hundreds of abandoned low-producing wells in the Baku oilfields are about to be fitted with pumps worked by central powers. The deep well pump is likewise being introduced into Rumania and Galicia with encouraging results.

Amongst the difficulties met by producers in some of the newer oilfields are those occasioned by precipitation of solid paraffin in the wells. Both the paraffination of wells and of the oil sands occurs in some of the American oilfields as well as in Galicia and Rumania, and to a small extent in Burmah. In America the wells and pump tubing are periodically cleared of wax, and de-paraffination of the sands has best been effected by using explosives. In Galicia wells were usually swabbed clean, and here also the virtue of explosives has been proved in the main Boryslaw-Tustanowice field. Various chemicals have been used for the same purpose, but their general utility has yet to be demonstrated.

Rumania is faced with a paraffin problem of some importance owing to the fact that most of the new and deep fields draw their supplies from beds of Meotic age, which generally yield an oil rich in solid paraffins. Many wells flowing open or under control become clogged with an amorphous paraffin which in time stops production. When natural flows have ceased in the richer fields the problem of keeping the wells and sands free from paraffins will have to be attacked. Paraffination takes many forms, and it is unsafe to generalise on its influence and the ways of diminishing its injurious influence. In Galicia the best, though costly, remedy was found in swabbing the wells and so drawing away the wax.

Gas-gasoline processes are extending rapidly owing to the continued demand for light-density gasoline for blending purposes. This development alone has enforced the greater use of gas separators and production methods which enable the gas to be collected from both flowing wells and those where oil is raised mechanically. Separators are made to deal with any pressure or volume of fluid, and certain makes will handle oils containing considerable quantities of sand in suspension. All the popular separators have arrangements for automatically regulating the fluid level in the vessel.

Gas-gasoline is being extracted from the gas either by compression or absorption methods. Compression processes are mainly

confined to rich gases containing over two gallons of stable condensate per 1000 cub. ft. of gas. Absorption processes are used for the lean gases containing less than, say, 2 gallons per 1000 cub. ft. Where, however, gas-lift is used for raising the oil, the gasoline is automatically trapped at a condenser in the circuit.

Absorption processes employ either a solid or liquid absorbent, the absorbed gasoline being recovered by heat applied in some convenient form. Liquid absorbents are suitably prepared distillates which on meeting in a state of spray, when cooled, a volume of gas, absorb the heavier gaseous products, which latter are recovered by distillation with open steam coils in a still.

For charcoal absorbers activated charcoal is used, and the absorbed liquid is abstracted by passing steam or other hot gases into the chamber so that all the absorbed material is replaced. The cycle provides for absorption, drawing off the gasoline with heat and cooling the charcoal by cool, dry gas. The charcoal process certainly yields a more stable product than the other processes owing to the selective properties of the carbon. The compression system yields a wilder variety of condensate which has to be weathered before blending.

Gas-gasoline plants are now in operation in most oilfields besides America, including Rumania, Galicia, Egypt, East Indies, Trinidad, Peru, Venezuela, etc., and in America, where the monthly production now reaches 110,000,000 U.S. gallons, there has been a development of portable absorption plants to compete with the compressor units so valuable for adjusting gasoline stations to suit constantly changing conditions.

New production problems are constantly arising to meet with new and unexpected conditions. The famous well, Royalite No. 4, near Calgary, Alberta, has brought to light a new type of well. Here, at a depth of 3700 ft. light oil and gas were encountered at an enormous pressure in a limestone. Until more wells have been sunk no one can say just how the fluid exists in the reservoir stratum. The well is now regulated to flow at a rate of about 20,000,000 cub. ft. of gas daily, from which some 550 barrels daily of 0.680 gasoline is abstracted in gas separators. The low temperature at the mouth of the well, due to the expansion of gas, causes all fittings to be covered with frost and ice. The only wells approaching this type were those of the upper Surakhani beds, Baku, Russia, where in a fine sand yields up to 70,000 barrels a day of 0.785 sp. gr. oil were obtained within a depth of 1000 ft. from great gas wells.

During the last year oil fires have been numerous through lightning and other causes. A very destructive well was extinguished in the Moreni oilfield of Rumania by mud pumped into the well after tunnelling into the side of a hill upon which the well was located,

and drilling into the casings with a rotary cutter. Many American oil and gas well fires have been extinguished by the impact of jets of steam or by snuffers, but in all cases rekindling could only be prevented by using a plentiful supply of water to cool all hot objects or quench smouldering material round the well. Most success has, however, been achieved by the firing of explosives over the mouth of the well thus momentarily breaking the continuity of the burning jet, and so causing its extinction. Approach to the wells has been made possible by wearing asbestos suits and arranging for jets of water to be played on those engaged in the work of suppression.

Foam mixtures are being increasingly used for choking fires in tanks and reservoirs, and investigations are being pursued to determine the best way of protecting tank farms from lightning.

In order to save the light products of oils and afford more protection against fire, greater care is taken in sealing tank roofs. Hermetic sealed roofs to tanks with breathing appliances are in general use. A floating roof is now used fairly extensively although the expense is considerable. Suitable heat reflecting paints are being used more on tanks in hot countries.

More extended experiments are being made of methods designed to increase the extraction ratio of oil sands. It is now generally agreed that in most fields more oil is left in the sands than is abstracted or is abstractable by usual production methods, and with this knowledge much attention is being directed to processes aiming at a reclamation of those remaining contents. Three processes are being tested on a commercial scale, viz :—

Water drive or flood.
Air and gas drive.
Mining methods.

In the Bradford field of Pennsylvania the flooding method is still being prosecuted with success, and it is claimed that ultimate yields will exceed several-fold those already obtained by pumping. Various arrangements and spacings of flood wells and oil wells are being tried to obtain the most complete scavenging of the oil sands. Various refinements have been suggested to hasten the progress or improve the efficiency of the flood, such as pumping water into the sands under pressure and adding chemicals like soda to the water which assist in the cleansing process. All such departures from a straight gravity flow involve costs which imperil the financial success of the process. Water drives are being initiated in some of the Mid-Continental fields, but it is too soon to say what the eventual results will be. It is generally necessary to drill rows of new wells to admit water and other rows from which the oil is pumped as the flood advances. As a rule water is admitted from

an upper water sand. The eventual unwatering of the sands with the possible recovery of a further proportion of the oil contents of the sands is a contingency which is being kept in sight.

Air or gas drives are being undertaken in a number of Mid-Continental oilfields, and the use of surplus gas for the purpose has led to some interesting litigation. Hitherto surplus gas from both oil and gas wells has been sold for gas-gasoline extraction, and the residue has been passed on to towns for domestic and power consumption. Those having made contracts for gas and incurred responsibilities object to the deflection of gas to the new purpose, although the producers are claiming that it is a legitimate property use, and that the eventual losses of gas will be insignificant.

Air or preferably gas, is forced by compressors into certain strategically placed wells, and its influence is noted on nearby wells. Usually it pays to drill special wells and arrange packers and tubing to direct the entry of the gas into the sands at the correct spot. In some cases the gas from an upper excluded gas source is admitted to the oil sand under its natural pressure. All wells in the path of the air drive must be carefully watched and the fluid level so controlled that no excessive losses of air or gas occur through bye-passing or other causes.

Properties usually respond within two or six months of introducing the air. Pressures gradually build up to some stationary figure between 50 and 250 lbs. per sq. inch at which the sands freely admit the gas. Weeks or months may be taken to reach this static pressure. In low-producing territory of the Mid-Continent where the sands are comparatively shallow, cored samples have shown that only about 20 per cent. of the oil contents of the sands has been extracted. Increased yields of 100 to 500 per cent. are frequent in wells of the 0.25 to 1 barrel per day class. Before arranging an installation wells are frequently tested with a portable compressor plant to ascertain which will take air freely, so that suitable air intake wells can be selected.

Both lease and royalty values have increased several hundreds per cent. where air, gas or water drives have been introduced. Some difficulty has been found in securing the co-operation which is necessary between producers to collect adequate acreage to make exhaustive tests or justify the installations of expensive plant.

Mining for oil is being successfully pursued at Pechelbronn in Alsace, but not without difficulties. Several explosions and fires have occurred notwithstanding the extreme care used in the workings. Oil mining is being actively followed in the Nienhagen field of Hanover, and in the Campina oilfield of Rumania shafts are in progress for a test in that exhausted field. Various tests are also being made in the United States oilfields where many ingenious

suggestions have been made for departures from straight mining practice. One widely-described method involves the driving of headings below the oil sands into which holes are drilled vertically upwards to let the contained oil drain into the workings. Until the price of oil has a much higher value it is unlikely that mining will be seriously entertained in any but the few fields where the sands are shallow and regular, evenly saturated and nearly horizontal, the caprock sound, water sources absent, the oil heavy and comparatively free from gas or light constituents. All technologists welcome the advent of such operations which will allow the subterranean problems of oil formation, concentration and recovery being examined in detail under natural conditions.

The value of cleaning wells is being increasingly appreciated and various devices have recently been introduced to facilitate the operation. In certain Mid-Continental fields portable air-compressor plants are being used for the purpose. Collections of sediment are ejected by admitting compressed air in tubes to near the bottom of wells after filling the wells with water. For the purpose of collecting a sufficient volume of air for a single expulsion of fluid a receiver is attached to the compressor where an adequate volume of air can be accumulated under pressure before it is admitted to the well. By repeating the process several times with the air pipes placed deeper and deeper all sediment in the well is ejected and the well is thoroughly washed out.

Some Californian operators flush their wells with hot oil when the production falls and considerable benefit has resulted from this practice. In many cases increased yields of 30 to 100 per cent. are obtained. If a temperature in excess of 130° F. is used it is claimed that the expansion of the casing may cause trouble and even damage a water shut-off. Swabbing is often conducted for clearing sluggish wells. Improved swabs are being introduced that automatically release the weight above the swab if inadvertently allowed to sink too deeply in the fluid, thereby preventing their being lifted by the available power.

Quicker drilling methods and improved transport arrangements due to motor propulsion are yearly influencing in a greater degree the competition to secure flush output from new fields. So intense is the activity in newly-proven pools that within a few months hundreds of rigs are often in operation and the flush is often taken off a new major pool in America within a year or two of its discovery. This fierce competition leads, at times, to the somewhat barbarous treatment of wells. Thus there has been a tendency to use heavier and heavier shots in sands giving sluggish yields. All features of this scramble have been recently illustrated in the new Panhandle field of Texas where, notwithstanding appalling transport difficulties,

some 560 rigs were in operation by July, 1926, with 25 to 30 more being added per week. In the desire to benefit at the expense of others, wells were shot with increasing charges up to 600 quarts of nitro-glycerine and at one well 870 quarts were fired. These excessive charges led to such a fracturing of the sands that water gained admission, and the practice was then modified to a general use of about 360 quarts or, say, three quarts of nitroglycerine per foot of sand.

Swabbing is very extensively practised in new fields of U.S.A. and especially at Panhandle where separation of paraffin chokes up the well, leading to falls from a thousand barrels or more to a few hundred within a week or two. The oil contains about 6 per cent. of paraffin wax and congeals at 50° F.

Some interesting pipe-line problems have been raised in providing for the transport of paraffinous oils with relative high temperature congealing point. The piping of oil from the Ceptura oilfield, Rumania, and the Panhandle field, Texas, has necessitated special heating arrangements, and means of expelling oil from lines before pumping ceases. The movement of oils at Smackover, Arkansas, necessitated the maintenance of a temperature not below 85° F., demanding heating arrangements at short intervals during the winter months.

In this connection it is interesting to record the recent movement of a 60,000 barrel cargo of Guanaco oil from the Orinoco delta, Venezuela, the specific gravity being 1·2 or 8° B. and the viscosity scarcely allowing it to flow. It would be more correctly described as a bitumen,and until recently it was assumed that this oil could not be handled at a cost which justified the attempt. In Trinidad a particularly viscous heavy oil was easily pumped by admixture with lighter varieties. Oil engines of the high compression type are now installed in connection with many pipe-lines where heat is not required to reduce the viscosity of the oil to be pumped.

The Monroe Gas Field, Texas, still maintains its reputation as the greatest gas field and producer of carbon black in the world. Recent wells have extended the area to 325 sq. miles, and the open flow of 406 wells on May 10th last was estimated at 3,000,000,000 cub. ft. a day. The reserve of gas is calculated at 2,100,000,000,000 cub. ft.; 37 plants produce from 500,000,000 cub. ft. of gas, 275,000 lb. of carbon black daily—about two-thirds of the world's supply. In addition 2,100,000 gallons of gas-gasoline are daily extracted from the gas.

More extended use of electrical energy is being made annually, but this is not usually introduced on new fields until the available gas supply no longer suffices for power purposes on the field. Only rarely are public supply services within reach of new oilfields, and

financiers are unwilling to embark on the erection of expensive generating stations until the permanence of a new field has been amply demonstrated.

Drilling Methods and Tools.

By Ashley Carter, A.M.I.Mech.E.

Considerable progress has been made by various Committees organised by the American Petroleum Institute regarding the standardisation of oil field equipment, and in a great many cases further research is being made with a view to permanent adoption.

It has been decided that four sizes of locomotive type boilers shall be regarded as standard, namely, 30 h.p., 50 h.p., 65 h.p. and 85 h.p. Boiler pressures will be 150 lb. and 175 lb. per sq. in.; 10 sq. ft. of heating surface has been taken as the basis for computing 1 h.p.

Important advances have been made as regards rotary drill-pipe, the following sizes now being standard :—

6⅝ in. O.D. (old nominal size 6 in.).
5⅝ in. O.D. (old nominal size 5 in.).
4½ in. O.D. (old nominal size 4 in.).
3½ in. O.D. (old nominal size 3 in.).
2½ in. O.D. (old nominal size 2½ in.).
2⅜ in. O.D. (old nominal size 2 in.).

Rotary drill-pipe will be known by its outside diameter.

The diameter of drill-pipe coupling has been increased to the outside diameter of tool joints, thus providing for a thicker and heavier coupling on many of the sizes.

Two classes of tubing have been decided upon, namely, plain or standard tubing and external upset. Plain tubing will be threaded 11½ threads per in., and external upset will have 10 threads per in. Extra long couplings have been provided in both types of tubing.

The outstanding operation in drilling during the year 1925 was that of the completion of a well by the rotary method in California to a depth of 7591 ft., this being the deepest producing oil well ever drilled by this system. This record is particularly interesting from the fact that the derrick and machinery were similar to numerous other rigs, and that no special equipment was employed. The formations penetrated were not particularly

hard, being of the same type as is found in most of the fields in the Los Angeles Basin. During the drilling of this well 154 cores were taken. The total cost of drilling the well was $170,423.67. The following table shows drilling time :—

Number of days drilling	172
Number of days fishing and milling	16
Number of days repairing	32
Number of days running casing	3
Number of days standing cemented	37

The casing used in this well was as follows :—

Jan. 2nd, 1925.	15½ in. cemented	988
April 5th, 1925.	8¼ in. cemented	5289
Sept. 16th, 1925.	4½ in. cemented through perforations ..	7305
Landed		7591

A notable advancement in rotary-drilling tools is that of building up the cutting surfaces with extremely hard metal coating, rather than dressing by the usual blacksmith's methods. The metal used withstands high temperatures. Tools built up by this method have given very satisfactory results in actual drilling, great economies being effected not only in increased life, but there is also a great saving in drilling time by the lessened necessity for changing bits.

The use of the rotary system has been extended during 1925 to fields which have hitherto been developed by percussion methods.

There has been an increased use of internal combustion engines and electricity as motive power on oilfields.

During the year under notice experiments have been made with a recording steam gauge attached to the drilling engine. A chart forms part of this apparatus from which can be ascertained how much time is occupied in a round trip ; how long is spent out of the hole ; the period of drilling time, shut down or merely rotating.

Retortable Oil-Yielding Materials.

By E. H. Cunningham Craig, B.A., F.R.S.E., F.G.S.

During the year there has been a considerable recrudescence of interest in the production of oil by retorting methods. The reason for this is not far to seek. Quite apart from the frequent scares of a coming oil shortage, scares which are quickly answered

by the optimists who would liken the United States to the widow's cruse, it is quite evident that it is only the discovery of new fields or deeper producing sands that has enabled production in that country to keep up with consumption. But the area in which new fields can be discovered becomes smaller every year, and a shortage, though not imminent, is definitely in sight, in spite of the campaign against waste.

Thus, alternative sources of supply have been closely canvassed, and the greatest, as has indeed been shown many years ago, is the oil-shales, and more especially those of the Green River formation in Colorado, Utah and Wyoming. At present it is only in Nevada, and to a smaller extent in California, that retorting for the production of oil is practised regularly, but much experimental work on retorts and retorting has been conducted, and much knowledge gained. At present the competition of free oil from wells makes it very difficult—and in some localities impossible—for a shale-oil works to be a paying proposition, but far-seeing men have realised that by the time shale-oil is required in quantity it will be required very badly, and therefore the industry must be started and organised *before* it can be expected to be highly profitable.

A very large number of retorts have been invented and tested, but, speaking generally, they can be divided into two classes, those that will produce a maximum quantity of high grade oil by possibly rather a complicated process, and those which will make a poorer class of oil in less quantity, but more cheaply, by a very simple process. Probably local conditions will decide in each case which class of retort will be most profitable to instal upon a large scale. It seems to be generally accepted that an all-in cost of a dollar a barrel for crude shale-oil must be aimed at if the industry is to be successful, and anything less than a dollar will be assured of success, if the crude be of good quality. It is doubtful, however, whether all the problems of refining the shale-oil have been satisfactorily solved.

Turning to Europe, the most important field to be noted is in Estonia, where a considerable advance has been made in the development of the Kukersite, and in the methods of dealing with it. The deposit, the richest of its kind in the world, is for that very reason difficult to retort satisfactorily. Yields as low as 47 to 50 gall. per ton have been obtained in vertical retorts, and a very heavy and refractory crude oil obtained. Other and more modern methods, however, have given, in works practice, yields up to 64 gall. per ton of a crude of 0·95 gravity, with a good percentage of petrol, while 5 or 6 gall. of light spirit can be scrubbed from the residual gases. Still better results will probably soon be

obtained, for the material is capable of yielding more than 70 gall. per ton of a light and more easily refined crude. The cost of the crude oil, produced on a large scale, will be rather less than 2d. per gall., after allowing for all overhead and incidental charges. The industry is only in its initial stage, but will probably attain large dimensions within the next two or three years.

In France and Spain some progress has been made. In the former both oil-shales and torbanites are being dealt with, and in the latter oil-shale only, but no industry of much importance can yet be said to have been established. The difficulty in most cases seems to have been in selecting a suitable retorting method, that is to say, one that will make an oil of good quality from the particular material, and at the same time be cheap to instal and cheap to operate. The latest news from France is that the latest type of retort installed is giving satisfactory results.

In the torbanite fields of Australia and South Africa development is still hanging fire, though these countries have great need of utilising indigenous sources of oil. They both probably await demonstrative proof of a retorting method suitable for their particular raw materials.

In Japan and Korea a scheme to utilise vast deposits of rather inferior oil-shale has been mooted, but has not yet reached fruition.

The shale fields of New Brunswick and the torbanite fields of Nova Scotia have not yet been exploited on practical and up-to-date lines, though a considerable amount of research work has been undertaken in studying the raw materials in each case: in these instances competition with free oil has no doubt had the effect of discouraging enterprise. The great asphaltic sands of the Athabasca River in Alberta, however, have come in for renewed attention and study, it being now realised that such a vast mass of bituminous material is an asset of world-wide importance. Various schemes for utilising these "tar-sands," as they are called, have been put forward, and much experimental work has to be done, both on the ground and in laboratories, to ascertain the best and cheapest method of making the bituminous content of the sand available. The Mines Department of Canada has taken a leading part in these investigations, and it seems to be admitted on all hands that the main difficulties of handling the material have been overcome. The oil must either be extracted *in situ* by means of steam pipes, with or without shafts and galleries of the Pechelbronn type, or the material must be quarried by steam diggers on a large scale, and the sand treated. The treatment must be either by a retorting or an extraction process, and there are advocates of both. The least expensive process must be sought for, but it may require experience of operating on a large scale over considerable periods

before any definite decision can be arrived at. In the meantime, it has been proved that about one barrel of oil per ton can be recovered from the average rich sands, and the oil so obtained, though heavy, can be dealt with in a modern cracking process to make petrol and a series of other marketable products. The cost of quarrying the sand from outcrop is confidently given as not more than 10 cents per ton. In Canada there is the greatest confidence expressed in the future of the tar-sand industry, if exploited on a large scale, like a low-grade mining proposition.

In Great Britain the most interesting occurrence of the year has been the publication by the Government of an auditor's report upon the Scottish Shale Industry, showing that with the present high costs of mining and retorting, the oil-shale industry is being carried on at a serious loss. The figures published have not been available to the public before, though they are not very surprising to technologists. After crediting the oil with the value of the ammonium sulphate produced, the all-in cost per gallon works out at 5·17d., a very high figure compared with the results that can be obtained in other countries, and in spite of very efficient refining, a loss of 1·4d. per gall. has been made during a period of six months. One of the chief causes of this unfortunate state of affairs is the decline in value of ammonium sulphate, which is now made in very large quantities from atmospheric nitrogen, and which will probably become even cheaper in the future. This tendency was obvious some years ago, and it was suggested that the high-temperature processes and vertical retorts used in Scotland were not suitable for modern conditions since petrol has become the most important finished product that is marketed. A complete reorganisation of the industry in retorting and refining might restore prosperity to it.

In this connection it may be noted that at last a beginning is being made with the establishment of a cannel oil industry. This was urged very strongly nine years ago by the Petroleum Research Department under the late Sir Boverton Redwood, and subsequently the Cannel Coal Committee formed by the Institution of Petroleum Technologists put the same proposals into practical form and reported fully upon them. Since then research has proceeded quietly but steadily, and improved methods of dealing with the various raw materials have been devised, and tested on a considerable scale. It used to be said that oil from cannel coal would not mix in all proportions with natural petroleum without causing a precipitate of pitch, but that only applied to oils formed in high-temperature processes. Now, quite light crudes with good percentages of petrol can be produced, mixing perfectly with petroleum, and easy to refine. Such crudes also, after topping, can be cracked

easily and successfully with the production of petrol of remarkably high quality.

The cannel coals, some of which are highly torbanitic, vary considerably in character and in yield of oil, and the cost of the crude oil naturally varies according to gallonage per ton obtainable from the raw material, but taking a general average, and making allowance for the different products in each case, it may be said that a crude oil of the value of 6d. per gall. can be made at an all-in cost of a fraction more than 4d. : a profit of from 1½d. to 2d. per gall. should be realisable, while in exceptional cases very much better results may be attained. In these circumstances, it is not surprising that both in Scotland and England plant is being installed to treat selected cannel coals. The industry is commencing on a somewhat small scale, but when its success becomes apparent, it is likely to become of considerable dimensions, and to do something to reduce the country's adverse balance of trade.

The above brief notes are sufficient to indicate that retorting industries in many countries have good prospects, first of all to supplement the supply of free petroleum, and later, as oilfields become exhausted, to take their place as a source of power.

Oil Shale.

By Victor C. Alderson, D.Sc.

The most notable events of the year have been the erection of the U.S. Government plant at Rulison, Colorado, the practical distillation improvements made by M. J. Trumble, the expected early completion and operation of commercial oil shale plants at Casmalia, California ; Elko, Nevada ; De Beque, Colorado ; Green River, Wyoming ; and Mt. Sterling, Kentucky ; besides pronounced activity in Tasmania, Estonia, Sweden, France, Canada, and Japan. The most valuable contribution to the industry as a whole has been the publication of "Shale Oil" by Dr. Ralph H. McKee and seven associates. Inasmuch as the first American book on the Oil Shale Industry, printed in 1920, is now out of print, "Shale Oil" is the only comprehensive American book on the subject now available. A comprehensive English treatise on the subject is now being prepared by David Brownlie, of London. From the economic point of view the active interst of oil companies and large financial interests has been important. This interest has been so intense and so many large tracts of desirable oil shale

acreage—desirable because of good title, high yield of oil, and low working costs—have been acquired that the supply of such acreage is well-nigh exhausted.

United States.

The Great Western Oil Shale Field.

Utah.—The oil shale field in Utah is vast in area and yields, in many places, a large amount of oil. Still better, however, is the possibility of mining the shale by the open cut or steam shovel method in many places where the hillside is one continuous mass of shale. The Uintah Basin alone contains 90 billion tons which, at the minimum of 15 gallons to the ton for commercially valuable shale as determined by the Government, will yield 33 billion barrels of oil. The oil shale laboratory of the Bureau of Mines is continued at Salt Lake City. The work consists of a study of fundamental principles involved in oil shale treatment. U.S. Senator King has introduced a Bill in the Senate appropriating $300,000 for an experimental oil shale plant in Utah.

Wyoming.—The oil shale field in Wyoming is mainly in Sweetwater County and is exposed on both sides of the Green River from the State line northward for more than 60 miles. A boring 23 miles north of the city of Green River showed 108 feet of almost continuous shale. The celebrated mahogany shale of Colorado extends into Wyoming and appears in all exposures. A characteristic of Wyoming oil shale is the small overburden and the feasibility of open cut and steam shovel mining. J. Edson Himes, of Chicago, owner of a large acreage of land 1½ miles north of the city of Green River, has given his oil shale a thorough large scale test in the Trumble plant at Albambra, California. The results were satisfactory and a 250-ton Trumble plant to cost $300,000 is to be erected and commercial operations begun at an early date. The cliffs on his land show 200 feet of shale above the plant site. One of the first oil shale leases granted by the Government has been taken by Messrs. Brown and Rosenberg, of Kemmerer, on 2000 acres in Lincoln county. The royalty is 2·5 per cent. of all shale oil produced.

Colorado.—The State of Colorado has been well advertised, everywhere, as containing the most valuable oil shale deposit in the world. This opinion is not based merely upon the high yield of oil but also upon the tremendous quantity available and the favourable economic conditions. The selection of Colorado as the site of the Governmental experimental plant is significant. A Pumpherston (Scotch retort) selected by the Bureau of Mines, is now being constructed under the supervision of James Shaw, a

Scotch oil shale engineer. A bank of these retorts, with a daily throughput of 60 tons (15 tons for each retort) is estimated to cost $20,000; auxiliary equipment $30,000; *i.e.*, $833 a ton daily throughput. Larger units would, of course, cost less per ton. At the beginning of operations the town of Rifle organized an oil shale celebration in honour of the event. The gathering numbered about 4000 persons. Naval airplanes were present, made flights to indicate the method of aerial surveys, and gave zest to the occasion. There are now in Denver two retorts, the Lamb and the Beeler-Thompson, which have advanced sufficiently to warrant use on a commercial scale. The Brown retort, in the De Beque field, is expected to be operating this spring. The Washington Shale Oil and Products Company, financed in Seattle, is now erecting a plant with an ultimate daily throughput of 1000 tons. The first unit is of 50 tons daily capacity expected to be in operation by May 1. Work on the necessary buildings, tram line, storage bins, and other necessities is now under way. The retort is being built by the W. A. Box Iron Works, from plans prepared by Carney Hartley, both of Denver. The retort will be of the Ginet type but improved on lines shown from experience to be advantageous. The Monarch Shale Oil Company is completing its plant 13 miles north of De Beque, in which a retort of the Ginet Process type has been installed. It is expected this plant will be completed and in full operation during the coming summer. J. H. Ginet, the inventor of the Ginet Process in describing his invention, states, "The retort proper is so designed that each and every particle of shale is subjected to identically the same temperature, through the lifting and showering of all the shale each six seconds, thereby evolving the taking off in their entirety the oil vapors under the ideal conditions which are necessary for a perfect eduction of shale oil." The Ginet process is patented not only in the U.S. but also in Canada, France, England, Brazil, Australia and New Zealand. An interesting test of De Beque oil shale was recently made at the Trumble plant. A sample representing an average of 40 vertical feet, thoroughly mixed, gave a yield of 39·70 gallons to the ton of 21·6° Beaumé. The co-operative work of the State and the U.S. Bureau of Mines has been continued throughout 1925.

The Great Eastern Field.

Kentucky.—Although the oil shales of Kentucky have not been advertised as well as those in the west, yet from the economic point of view, *i.e.*, low cost of mining, markets for labour supplies and products, transportation, and nearness to centres of population,

they are worthy of serious attention even though the yield of oil per barrel is less than from the richer shales in the Great Western field. Until the past year the Kentucky oil shales have been neglected and their value unknown beyond a small circle. Recently interest has been aroused through constructive and conservative publicity. Activity centres about Prof. C. S. Crouse at the University of Kentucky. On the basis of work done in the University laboratory by Mr. Job Hedges and Prof. Crouse, a pilot retort is being erected at Newark, New Jersey, to be followed by a commercial sized retort at Irvine, Estill county. Prof. Crouse has devised another retort and has erected an experimental plant at Mt. Sterling. The retort is of horizontal, revolving cylinder type, internally heated similar to a fire tube boiler, with the heat passing through the tubes and the shale surrounding them. A test made on Montgomery county shale gave a yield of 33·5 gallons of oil to the ton. A sample of oil tested at the Pittsburg Testing Laboratory, gave 24·7 per cent. gasoline and naphtha, and 19·9 per cent. kerosene. It is expected that a commercial sized plant of this type will be erected at Mt. Sterling, Kentucky, this summer.

Indiana.—According to the report of Dr. W. N. Logan, State Geologist, Indiana contains 45 billion tons of oil shale that will yield from 10 to 40 gallons of oil to the ton. The crude shale oil contains from 30 to 34 per cent. of light oils, about 50 per cent. of heavy oils, and about 18 per cent. of tar and coke. The sulphur content varies from 0·65 to 1·98 per cent.; the nitrogen from 1 to 1·98 per cent. Prof. A. W. Homberger, of the University of Louisville, has made a careful study of the New Albany, Indiana, oil shales. Tests on 26 samples varied from 8·3 to 12·1 gallons of oil to the ton, with an average of 10·31 gallons. The tests represented four different methods of retorting—viz., atmospheric pressure, the use of superheated steam, reduced pressure, and the insertion of copper in the vapour line. His conclusions, for this type of shale, are as follows:—

First, that the superheated steam method of retorting is the best, as far as the yield of oil and ammonium sulphate is concerned.

Second, that the reduced pressure method is the best as far as the quality of the oil is concerned and that this is due to the internal reactions of the retort.

Third, that the superheated steam method gives the larger percentage of nitrogen and sulphur, because a part of the original bitumen is carried over by the steam.

Fourth, that the sulphur and nitrogen are in the shale and also the oil, in combination with each other, and that the percentage of the two elements in the oil is dependent upon the conditions of retorting, for these conditions may be for the sulphur to recombine

with the hydrocarbons or that the nitrogen may also recombine with the loss of the sulphur.

Fifth, that the iodine numbers and consequently the true unsaturation is proportionate to the specific gravity of the crude.

Sixth, that the loss to sulphuric acid does not mean that it is a test for the unsaturates present, but is a sum of the unsaturates and the compounds that are soluble in the acid.

Seventh, that the retorting for oil is best done by allowing slow heating and plenty of time in the retort.

Western United States.

Nevada.—Oil shale operations in Nevada are limited to the work of R. M. Catlin at Elko. After nine years of experiment and the building of five commercial sized retorts Mr. Catlin has evolved a commercial plant that is economically profitable. The shale is mined from a five foot seam which has maintained a constant average for a distance of 700 feet, on a dip of 25 degrees. Methods of electric drilling, mining, and handling the shale have been constantly improved. The retort is of the vertical, blast furnace type, made of steel and lined with fire brick with three zones, a distillation, a fire, and an ash zone. The intent of Mr. Catlin has been to devise a process to treat oil shale in mass, in a retort of large capacity, of few working parts, low maintenance and operating cost, and simplicity of operation. In this he has succeeded. The retort has an initial capacity of 90 tons; a daily throughput of 144 tons in 24 hours has been attained. In addition, a refining plant of 600 barrel capacity and a wax plant have been erected. Gasoline, fuel oil, wax, and high grade lubricating oils have been made and marketed. W. L. Sheeler, Superintendent, states authoritatively that, "costs in mining, retorting, and refining, showed that on large scale operations the oil shale industry is a paying operation; that high costs written so much about by people that had no way of confirming the figures, were very misleading as all costs gained in such manner are a "state of mind," unless shown from actual operations, and from the disposal of products in competitive markets with other petroleum products. By making finished products and marketing them we obtained actual costs, which are not to be had from any other source. Our operations have produced over a million gallons of crude oil, a retort that is economical to operate, a mining cost that we believe is comparable to the cheap metal mining costs of the present day, and refined products that will stand up and meet the competition of the highest grade petroleum products on the market to-day." R. M. Catlin says: "We ran one single unit experimental plant until all our storage tanks were full and, having demonstrated my

principle, we are awaiting development in the oil situation before attempting to enter the commercial field."

California.—A most striking advance, in a commercial way, has been accomplished at the plant of the N. T. U. Company at Sherman Cut, near Casmalia, California, under the technical direction of Geo. W. Wallace. The first installation was a 20 ton plant, then a 40 ton plant, and now a still larger plant is being erected. The principle of retorting is a radical departure from the Scotch plan. True, both types are vertical and the feed is at top, but in the Scotch the hottest part is at the bottom and the draft is upwards; in the N.T.U. retort this plan is reversed; the draught is downward within a vertical steel shell with temperature control. Very accurate tests have been made to determine the quality and quantity of the oil produced; also the cost of operation. An average of four tests made by G. W. Wallace on the 40 ton plant gave a yield of 29·40 gallons of oil to the ton at an operating cost of $1·375 a ton. A test made by Smith, Emery & Company, engineers of Los Angeles and San Francisco, gave a yield of 38·89 gallons to the ton at an operating cost of $1·18 a barrel. In the Wallace test the cost per ton for mining and crushing alone was $0·4326; in the Smith, Emery & Company test this was $0·3914. It should be stated that the low cost of mining and crushing results from open cut and steam shovel mining. The results of the work thus far done have been so satisfactory that a contract has been made with the Union Iron Works Company, a subsidiary of the Bethlehem Shipbuilding Company, for the erection of a $500,000 plant to treat 400 tons a day. This is eventually to be enlarged to a 1000 ton plant. A contract has been made with the Associated Oil Company of California for the delivery of 10,000 barrels of shale oil for local consumption.

The Corfield process is unique in that it consists of 24 one-ton retorts, placed on a turntable. One revolution in two hours gives sufficient time for complete distillation. As the cycle is completed each retort is dumped, refilled, and started on another cycle. The retort has been tested on Brazilian, Utah, and other shales. The Distillation Products Company, which owns the patents on the Corfield retort, has contracted with the Diatorn Products Company to erect a 300 ton Corfield plant at Casmalia, to be in operation by July 1, 1926.

W. C. Kirkpatrick, of the National Refining Process Corporation, Los Angeles, is engaged upon a new retort which will probably be completed in 1926. The process is intended to cover such essential features as continuous charge and discharge, perfect control of heat application, time temperature contracts, and carbonization. The process will be of the single cycle type. The crude is never

exposed or withdrawn but goes at once to the refining system from which the various products are drawn, ready for the market.

At the University of California the importance of oil shale research is being recognized. An oil shale laboratory is being equipped with two retorts; one an electrically heated and controlled shaft type with multiple coil condenser; the other a laboratory sized N.T.U. retort with condenser, dephlegmator, and the necessary auxiliary equipment. Plans for the future include a laboratory for the refining of shale oil.

At the Trumble plant, at Albambra, there has been steady, consistent progress—theoretical, practical and technical—Mr. Trumble, from long experience in the oil business, is an expert in judging oil; consequently his main aim has been to produce oil from shale that is not spoiled in the operation. His tests fully justify his claims that the oil he produces is a sweet, well saturated oil. During the year many details of construction have been improved, like a superheater that will stand up under the imposed conditions, and valves for the retorts that must be absolutely secure, without leaks and yet easily opened and closed. Not only have many tests been made but their geographical range has been wide. Besides tests from many deposits in the U.S. shale has been sent from England, Scotland, France, Estonia, Australia, and Brazil for exhaustive treatment. Besides making test for the yield of oil alone extensively minute details have been recorded in temperatures, pressures, heat balance, and other details—a mass of information collected by his staff of chemists and engineers which will be invaluable in the construction of plants and in the technology of oil shale. The plant now in use handles 10 tons in 24 hours and operates so smoothly that a 98 per cent. extraction from the raw shale is secured and the shale oil produced is more valuable than well oil. It is Mr. Trumble's opinion, after much experimentation and serious deliberation, that good profit will result from refining the shale oil in such a way that the lubricating and wax cuts can be taken off and marketed as lubricating oil and paraffin wax. The balance, of course, with the exception of pyridene would be cracked into gasoline. His process is so flexible that the raw shale can first be retorted and the various products taken off separately and put thorough whatever refining process may be necessary to make marketable products in the region where the plant is located.

Spain.

The plant at Puertollano, 110 miles south of Madrid, has continued in successful operation during 1925. The products have a local market and the project continues to be a financial success.

Attention has been called recently to a new field called the Lux Oil Shale Field, on the north coast of Spain in the province of Oviedo. The full extent of the field is not yet determined, but indications point to a very large area of oil shale deposits. The tract thus far explored covers only 2223 acres. Dr. J. W. Norman of London tested the shale and reported a yield of 30 imperial gallons of oil and 25 pounds of ammonium sulphate to the ton. Water, plant sites, transportation, climate, and other economic factors are favourable. The development is sponsored by Lt.-Col. R. H. F. Standen, of London.

Brazil.

Brazil is notably poor in a domestic supply of coal and oil but she has extensive deposits of oil shale, which she is now exploiting Prof. Marcus A. Chase, of Mackenzie College at Sao Paulo, has done experimental work on a small scale. A test of a ton of Brazilian oil shale treated at the Trumble plant in California, under the personal supervison of engineers from Brazil, gave 31 gallons of oil of 32° Baumé. As a result of this test a 500 ton Trumble plant is to be erected in Brazil, plans for which are now being drawn.

China.

The province of Shansi, in Northern China, has evolved a plan to utilize her oil shale deposits and to eliminate the importation of oil. The province now imports oil to the value of $3,000,000 annually. The provincial authorities have outlined a 10-year programme, with a yearly appropriation of $300,000, for the erection of distillation plants to costs approximately $200,000 each, as fast as conditions warrant. It is estimated that on account of cheap labour and low cost of mining, by steam shovel methods, a profit of $70,000 a year can be obtained.

Japan.

The Fushun coal and oil shale field is situated 25 miles east of Mukden, in Manchuria. The coal field is the largest in the Far East; the combination of coal and oil shale makes it the most remarkable deposit of its kind in the world. The field is 20 miles long and 1½ miles wide. The upper strata consist of shale; beneath this lies a deposit of bituminous coal. Neither the coal nor the oil shale is of the highest quality yet the great amount of each, the possibility of mining with steam shovels, and the low costs of operation makes the whole deposit commercially profitable. The total reserves of oil shale are conservatively estimated at

5,500,000,000 tons to yield 1,100,000,000 barrels of oil or enough to supply six million barrels annually, for nearly 200 years. Viscount Masatoshi, of the Tokyo Imperial University, after a careful investigation, is of the opinion that this deposit will prove to be one of the greatest assets of the Japanese Empire. The South Manchurian Railway and the Japanese Government are equally interested, both in supplying funds, and the railway in the installation and operation. The Japanese Government has granted the railway company the authority to issue bonds to the amount of 6,500,000 yen to carry out the plan. After a careful investigation and experimental work, the Pumpherston (Scotch) retort has been selected and is now being erected to handle 35,000 tons of shale a year. The remainder of the plant will follow closely the Scotch plan for the production of gasoline, ammonium sulphate, lubricating oil, and other products. The Manchurian shale is not rich in its oil yield; that is, it yields only 12·5 to 20 gallons of oil to the ton, but the underlying coal and the low cost of mining will make the project commercially profitable. The total cost of production is estimated at $2·26 a ton and the market value of the products at $3·11. This leaves a profit of 85 cents. a ton. The international and economic effect of Japan's entrance into the coal and oil shale industry should not be overlooked. In the first place, neither the coal nor the oil shale at Fushun can be worked profitable apart from the other, because the oil shale forms a thick over burden which must be removed before the coal can be mined. Both are susceptible to steam shovel excavation. Japan's domestic, naval, and commercial oil requirements will be taken care of for centuries without recourse to imported oil. In the time of war she would be independent of foreign oils. All in all, the world must commend Japan for her far sightedness and view with deep interest the outcome of her efforts.

Refining.

By J. McConnell Sanders, F.I.C., F.C.S.

General.—During the year 1925 the predominating characteristic of refining operations generally was the decided tendency to employ improved methods making towards increased recovery of valuable products, and the avoidance of unnecessary losses.

According to C. E. Bowles[1] the gasoline recovered from crude run to stills was 34·9 per cent. as compared with 33·1 per cent.

[1] *Oil and Gas J.* **24** (39), 144.

in 1924 and 30·9 per cent. in 1923, this referring to refineries operating in the United States. He points out also that the gasoline content of the average crude distilled was lower in 1925 than in 1923.

In a paper read by L. Schmidt at the Fort Worth meeting of the W.P.R.A. on March 3rd, 1926, it was stated that the losses from evaporation of gasoline in the average Mid-Continent refinery during 1925 was probably half as great as in the years 1923 and 1924, and he deals specifically with the use of vapour-tight tanks, circulating pump systems for treating in place of agitation by air blowing, recovery of uncondensed still gases, and floating roofs for storage tanks.

In this connection it may be pointed out that the use of aluminium paint for covering storage tanks received a great deal of attention in the year under review and its application is becoming more general.

A circular by H. H. Hill, of the U.S.A. Bureau of Mines, entitled "The Gasoline Situation," mentions the following as factors influencing the higher average yields of gasoline obtained by refiners:—(*a*) Improved fractionating equipment; (*b*) more general use of cracking processes; (*c*) use of gasoline from natural gas; (*d*) reduction of evaporation losses; (*e*) a slight lowering in the volatility of gasoline marketed; and (*f*) a more general use of improved equipment.

According to preliminary statistics furnished by the U.S.A. Bureau of Mines, 26·5 per cent. of the gasoline produced in 1925 was derived from cracking processes, and all indications point to a tendency for this percentage to increase.

It is interesting to observe the influence of increased activity in the sphere of cracking processes, upon the average prices of fuel and gas oils. According to C. O. Wilson[2], an increasing number of refiners with cracking installations never offer any gas oil to customers as they find it more profitable to crack the product and secure a larger recovery of gasoline.

The year 1925 was noteworthy as regards crude oil production in the United States, all records for previous yearly production being broken. The bulk of this increased output came from the heavy Smackover fields and from California. Much of this heavy oil was used as fuel without refining, and even when refined the fuel oil residuum was large. In spite of the increased supply average fuel oil prices were higher in 1925 than in 1924, and this was due to the fact that improved refinery plant efficiency and modern cracking methods made it possible to secure more gasoline

[2] *Oil and Gas J.* **24** (39), 125.

and other light products from the heavy crudes, and this in turn meant less residuum circulating in refinery operations.

To offset this, however, it should be pointed out that recent and growing developments in the use of the Diesel engine for marine purposes had already begun to have an influence upon the character of the fuel demanded for bunkering, an influence which will undoubtedly be felt in greater measure during the coming year.

A somewhat novel viewpoint is presented by H. J. Struth,[3] who points out that over a period of three years the output of closed automobiles has steadily increased, being 43 per cent. of the total output in 1924 and estimated to be 57 per cent. in 1925. He takes this to indicate that the motor car can no longer be classed as a luxury, but as a necessity in our every-day pursuits, and that the increased demand for closed cars points to a growing tendency among motorists to utilise their cars all the year round. This means a longer average motoring season, and consequently a greater average annual consumption of gasoline and lubricating oils.

Since 1918 the average consumption of gasoline per mile run has steadily decreased owing to improved carburation and engine design, but the closed car has enabled more miles to be run annually, with a consequently greater annual consumption.

While the above remarks refer primarily to the United States a similar tendency is observable in Europe, and the increased output and use of automobiles has brought with it a demand for more roads and better road surfaces which has not been without influence upon refinery operations, which are largely controlled by the exigencies of the public consumer.

Thus it was that refiners during 1925 devoted considerable attention to the manufacture of paving asphalt, and a new and rapidly-increasing industry has sprung into being, covering the manufacture of bituminous emulsions, asphaltic solutions or "road oils" and similar preparations suitable for road surfacing. This renewed activity in the bitumen markets has been of special value to Mexican refiners, who have found new outlets for their heavy asphaltic residuals.

In the United Kingdom, British receipts of petroleum products from abroad have constituted a record, although according to the statistics the increased importations were confined to crude and gas oil consignments, the other products showing a decrease.

In the opinion of the *Petroleum Times* the growth of the British refining industry is due to the growing activities of the refineries at Swansea, Shell Haven and Grangemouth, at which centres

[3] *Oil Trade* **17** (4), 34.

about 100,000,000 gallons more of crude was handled in 1925 than in 1924.

Viewed as a whole, refining methods during the year under review have not exhibited any startling changes or developments.

Plant and processes already referred to in former reviews have been improved in a few instances or their sphere of application enlarged; quite a number of them have died a natural death.

Cracking processes have continued to augment the bulk of patent literature, but are dealt with in a special review.

Some of the more interesting contributions to the literature of the subject, and the patents completed during the year, are briefly summarised below.

Distillation.—Although actually patented in 1923, the high vacuum process of J. E. Schulze[4] did not attract a great deal of public attention until 1925, when considerable publicity was accorded it by the technical press of the United States.

It is well known that in oil distillation under reduced pressure the effectiveness of the latter becomes proportionally greater the nearer it approaches to absolute vacuum.

It is also found in actual practice that it is advisable to employ open steam in addition to reduced pressure.

Schulze employs a vacuum of under 5 mm. of mercury, and claims that he uses no steam in order to obtain from heavy or residual oils a range of lubricating oils which need no acid treatment or filtration.

He employs a specially braced type of still in which all seams and connections are electrically welded. To minimise resistance to vapour flow the still is equipped with a number (10) of large diameter vapour lines which rise but a short distance above the still before bending sharply downward to a condenser. In order to keep the vapour lines as short as possible, the condenser is placed parallel to and close to the still.

To prevent local overheating of the still bottom a specially designed furnace is used, in which radiant heat is spread evenly while preventing direct contact of the flame with the still bottom.

In a paper by L. Steinschneider entitled "The Principles of High Vacuum Distillation of Mineral Oils"[5], the author refers to the fact that a lecture given by him in 1912, before the Eighth International Congress of Applied Chemistry, at Columbia University in New York, on the favourable results achieved in the high vacuum distillation of petroleum, met with little more than academic interest. He traces the rapid growth of interest

[4] U.S.P. 1,448,709.

[5] *Journ. Inst. Petr. Techn.*, Vol. II, No. 53, Dec. 1925.

in the process as far as it concerned the United States from that date, although in Europe the method had already been adopted. His paper further deals with the theory underlying the process as well as its practical application, and concludes with the statement that the advantages of high vacuum distillation are such that the capital outlay involved in its adoption is usually covered in less than one year.

Distillation with the aid of vapours other than steam has not been the subject of many new developments. The experiments of Wandyez, Suknarowski and Chumura[6], using superheated petrol vapour, were described in the review for the previous year. They also describe[7] a series of similar experiments using superheated benzol vapour as a heating medium, and claim similar favourable results for the products.

Another variety of gas-assisted distillation is patented by M. G. Paulus[8], who uses a container mounted on a still setting and provided with a series of inclined tubes connected to headers, through which oil is caused to circulate. The lower ends of the tubes are fitted with internal gas jets through which gas may be injected upwards so as to assist and promote circulation.

"Film evaporation" has been the subject of several patents in past years, and L. E. Hirt[9] combines this with gas in a process in which the oil passes in thin films through a series of tubes through which a gas, "differing in character from the vapours of the hydrocarbon being distilled," is forced so as to remove mechanically the vaporised components of the oil.

A patent by R. A. Dornés[10] claims that oil may be vaporised and partially purified by submitting the vapours to a series of expansions and reheating. The vapours are then mixed with steam and the process repeated, being finally subjected to different temperatures and pressures in order to bring about condensation.

A somewhat similar process is claimed by A. R. Earle and T. W. Reed[11], whereby oil is continuously distilled by heating it under pressure by means of steam, releasing the pressure, and allowing the oil to pass into an expansion zone where it vaporises. The vapours are fractionally condensed, the unvaporised oil withdrawn, further heated without allowing vaporisation, and passed into an expansion zone at a pressure below atmospheric. This process is repeated.

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[6] *Chem. Zentr.*, 1925, **96** (I.), 595.
[7] *Petroleum*, 1925, **21**, 641-650.
[8] U.S.P. 1,541,274.
[9] U.S.P. 1,559,701.
[10] U.S.P. 1,526,534.
[11] U.S.P. 1,567,429.

In a process invented by H. F. Perkin[12], a column is packed with a material of good heat conductivity and oil vapours are passed through this. The temperature of the column is maintained slightly above the end point of the desired cut.

The vapours are then passed through a similar apparatus which is maintained at a temperature within 3° of the end point ot the cut, and the residual vapours are condensed.

In the process patented by F. M. Hess[13] a distillation tower is provided with hollow heating plates placed zig-zag fashion, through which the oil flows by gravity to a residuum receptacle. The heating plates support screens which carry a catalytic material, while superheated steam passes upwards through a system of tubes.

A still invented by H. G. W. Kittredge[14] consisted of two receptacles; one had an arched top which was exposed to the heat from a furnace while its lower portion was protected from direct heating by means of insulating brickwork. The furnace gases pass over the first vessel and then through the internal flue of the second receptacle, which is surmounted by a tower and an attached condenser. The liquid level in the second vessel is so maintained that its internal flue is completely immersed. Oil passes through the first vessel and then to the second.

M. F. de Bajligethy[15] describes a still which consists of a boiler upon which a number of drums are mounted and which are provided with detachable heads at the ends which project from the boiler. The inner ends of the drums are provided with inlet pipes which at one part are formed into heating coils which are mounted in a furnace. The outer ends of the drums are provided with nozzles which can discharge into the boiler.

An evaporating still is patented by D. L. Newton[16] which consists of a vertical shell divided into four compartments by horizontal partitions. Oil is fed into the first or lowest compartment, which communicates with the fourth or uppermost compartment, by means of small bore tubes. From this compartment the vapours are drawn off. A number of large bore tubes lead downwards from the fourth compartment to the second, which contains residual oil, and into which steam is injected. The third compartment surrounds both sets of tubes, and is supplied with a heating medium.

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[12] U.S.P. 1,541,274.
[13] U.S.P. 1,552,698.
[14] U.S.P. 1,561,169.
[15] U.S.P. 1,562,690.
[16] U.S.P. 1,567,455.

P. Young[17] proposes a new method of construction for a coking still, in which the bottom is formed of thick plates bound together with thin plates. The latter are said to adapt themselves to changes caused by thermal expansion, while they can be readily and cheaply renewed.

A novel condensing arrangement is claimed by E. W. Isom and J. E. Bell[18], and consists of a tank for the condensate and a cooler which are connected so as to form a closed circuit from tank to cooler and back to the tank. The vapours to be condensed are injected below the normal level of the condensate in the tank, means being provided for withdrawing the liquid condensate from the latter.

Still another system of condensing is proposed by the Power Specialty Co.[19], in which the vapours are treated in a number of rectifying columns at successively lower temperatures and finally exhausted to a condenser. Part of the liquid from the condenser is used as a reflux liquid in the final column, while the condensate formed at any stage is passed through pipe coils within the lower parts or condensate sumps of all the later stages and serves to redistil the later condensates. Each condensate after passing through the final cooler is partly returned as reflux liquid to the next earlier stage.

Treating.—An improved method of operating his well-known method was patented by Dr. Edeleanu and his Chief Chemist Dr. W. Hess[20]. This consisted in a system of treating oil with liquid sulphur dioxide in stages, the "extract" obtained from the treatment of one fraction of the oil being used to treat another batch of oil until its extracting power was exhausted. In this connection it may be mentioned that Dr. Edeleanu has proposed to treat the charging stock for cracking processes by his method, and claims to procure cracked products which are superior to the ones usually obtained in that they require much less acid for treating.

A new method of applying the hypochlorite treatment for desulphurising is claimed by H. D. Demoulins and F. H. Garner[21], who propose to spray a solution containing an alkali with a hypochlorite or other oxidising agent into the vapours at the outlet of a dephlegmator, fractionating column or scrubber.

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[17] U.S.P. 1,564,312.
[18] U.S.P. 1,563,492.
[19] E.P. 239,208.
[20] U.S.P. 1,526,665.
[21] E.P. 216,918.

The use of Fuller's earth for refining distillates in the vapour phase after the method of Gray is claimed by U. F. Clemons[22], who describes an oil still provided with a large dome in which is supported a bed of the earth through which the vapours have to pass.

P. W. Prutzman[23] claims an improvement by treating oil at a high temperature with absorbent earth in an atmosphere of inert gas, so as to prevent oxidation.

A novel material for treating oil is claimed by H. Reinbold[24] who impregnates hydrous silicic acid with lithium chloride, or lithium chloride combined with aluminium chloride, by treating an aluminous silicate clay with hydrochloric acid and adding lithium chloride.

A combination of absorbent material and active chemical is also proposed by the A.G. für Chemiewerke[25], who claim a method of purifying vegetable or mineral oils by the use of porous substances such as Kieselguhr, carbon or colloidal silicic acid which have been impregnated with small quantities of sulphuric acid, the pulp pressed to remove excess of acid, and then dried by heating until sulphurous fumes are given off.

The application of absorbent material is also embodied in a number of other patents taken out by P. W. Prutzman and his collaborators. Thus with C. J. von Bibra he claims[26] a process in which the absorbent material is mixed with water so as to form a mud which is mixed with the oil. Heat is then applied so as to drive off the water and thus allow the solid decolorising material to come into intimate contact with the oil.

Another of his patents[27] refers to a method for decolorising oil in which part of the latter is mixed with the powdered, porous absorbent so as to form a paste or mud, the mixture allowed to rest until all the air has been dispelled from the pores of the absorbent. The remaining portion of the oil is then heated to about 176° and added to the mud, the spent absorbent being then separated mechanically from the oil.

Again, P. W. Prutzman and P. D. Barton[28] claim a process in which acid-treated oil is agitated with powdered absorbent material which has already expended its absorbent power in removing impurities from a tar-free oil, and is still charged with the latter,

[22] U.S.P. 1,525,808.
[23] U.S.P. 1,551,909.
[24] U.S.P. 1,558,631-2.
[25] E.P. 239,169.
[26] U.S.P. 1,562,001.
[27] U.S.P. 1,561,999.
[28] U.S.P. 1,562,000.

the process serving to remove the acid tar formed during the acid treatment.

A somewhat similar process is described by S. H. Diggs[29] in which residual hydrocarbon oil is treated with sulphuric acid, the sludge removed and the oil agitated with slaked lime in suspension, or before removing the sludge, fuming acid may be added and the combined sludges removed.

The last two processes taken together seem to constitute the so-called "Dry" method of treating lubricating oils in which the emulsification so often experienced when attempting to neutralise and wash an acid-treated oil, is avoided by treating the latter after separating the acid sludge, with a mixture of lime and Fullers earth, the latter being then separated by filtration.

A quite different method is provided by S. Coblentz[30] who, after treating the oil with acid and separating the sludge, emulsifies it with a salt solution, the emulsion being then subjected to "cataphoretic action."

For the rapid separation of sludge from oil J. W. Weir claims[31] a process in which the mixture is supplied to a centrifugal machine, and while the sludge is thrown out to the periphery of the rotating member, a solvent for sludge is fed in close to the periphery and continuously discharged.

The emulsion difficulty when neutralising acid-treated oils is also dealt with by a patent taken out by J. F. Faber, H. C. Hanna, and M. L. Chappell[32] who claim to prevent emulsification by adding salts of petroleum carboxylic acids, obtained by extracting these acids from crude oil by means of aqueous solutions of a metallic base.

In the manufacture of lubricating oils considerable attention has been directed towards the removal of wax from what are known as "long residuums," that is to say the residual oil obtained in the primary distillation of a paraffin base crude, which contains not only the eventual material for making Bright stocks, but also those fractions which are usually obtained as heavy wax distillates.

In an interesting paper by M. B. Miller, read before the petroleum division of the A.I.M.E. in New York, the advantages of the centrifugal method of separating the amorphous wax instead of the more cumbersome "cold settling" process, are fully described. It is pointed out that while "neutral" oils obtained by ordinary methods were too low in viscosity, the Bright stocks were too high, hence blending was necessary for market requirements. By the centrifugal process it is possible to dewax the total lubricant cut

[29] U.S.P. 1,521,282-3.
[30] U.S.P. 1,540,929.
[31] U.S.P. 1,525,016.
[32] U.S.P. 1,562,156.

from a crude and in 1925 the centrifugal process has been developed so as to allow the dewaxing of overhead stocks produced when running crude oils to flux. While distillation with vacuum, or with fire and plenty of steam, gave distillates in which all the wax was amorphous, the use of the centrifuge allowed these to be dewaxed without any previous acid treatment.

In this connection mention may be made of a patent taken out by S. H. Hall[33] for an improved bowl for separating wax by the centrifugal machine. The centrifugal bowl is provided at the outer rim with a number of pipes for the discharge of the wax. These pipes are heated electrically, by which means the heat for rendering the wax fluid enough to run off easily, is localised, and does not warm the cooled mixture of oil and naphtha from which the wax is being separated.

The separation of crystalline from amorphous wax is claimed by E. Petty[34], who in one patent describes a process in which paraffin base oils are chilled and centrifuged, the wax obtained being then distilled to drive off the crystalline variety, the amorphous form being left as a residue.

In an other patent he claims a method for preparing Bright stock by using a paraffin base crude from which the wax distillate has not been removed, chilling it and removing the wax by the centrifuge. The wax-free oil is distilled and the residue blended with a low-boiling petroleum distillate. The diluted stock is then treated with acid and alkali and the light distillate distilled off.

With the object of avoiding local supercooling or "shock chill" when precipitating wax from petroleum by the "cold settling" process, L. O. Jones[35], circulates brine through coils in a tank containing the oil, and a portion of the brine is also circulated through a chilling apparatus, so that the temperature of the brine is kept about 5° below that of the oil.

In the manufacture of transformer oil W. T. Maloney[36], proposes to anticipate possible sludge formation by oxidising the sludge-forming components. He treats the oil with a gas containing oxygen and then precipitates the oxidised substances by the addition of an alkaline reagent.

For the production of lubricating oils with a green fluorescence R. W. Hanna, O. E. Cushman and T. W. Doell[37], mix the oil which is derived from a cracking process which has been operated under conditions of temperature and pressure conducive to the formation

[33] U.S.P. 1,525,808.
[34] U.S.P. 1,559,981-2.
[35] U.S.P. 1,558,619.
[36] U.S.P. 1,540,218.
[37] U.S.P. 1,566,000.

of a polymerised and stabilised viscous oil stock, with a lubricating oil obtained from petroleum by a process carried out below the stabilising conditions.

Among refining methods specially applicable to the manufacture of kerosene, those of R. W. Hanna and J. F. Brooks may be mentioned. In one of these[38] oil is preheated to 200° F. and forced into jacketted washers together with sulphuric acid, preferably containing 15 per cent. of SO_3. The mixture is maintained at about 215° F. for from 30 to 60 seconds, and then immediately cooled. It is claimed that the preheating reduces the time required for accomplishing useful reaction and thus diminishes the decomposition of the reaction products, while at the same time the acid becomes less diluted, with consequent economy. Decomposition is also arrested by the rapid cooling.

Another patent[39] varies the above method by heating the lamp oil distillate to 93°, treating with acid, the oil and acid together being then continuously forced into a closed circuit while their temperature is maintained at 102°.

Miscellaneous.—A method for separating aromatic from aliphatic and hydroaromatic hydrocarbons is claimed as novel by E. Eichwald[40] who adds a substance containing furfuraldehyde to the oil. Separation into two layers takes place, the furfuraldehyde layer containing the aromatic components of the oil.

According to R. F. Davis[41] oil may be purified by exposing it to the action of copper oxide under the influence of light.

W. Kritshevsky and H. C. Prutzman[42], treat kerosene with chlorsulphonic acid, then with sulphuric acid, and finally with a solid absorbent colloid.

The recovery of spent Fuller's earth or similar decolorising material is the subject of patents taken out by F. W. Hall. In one[43] he removes occluded colouring matter by treating the spent earth with acetone mixed with either gasoline or benzol. In another[44] the earth is subjected to the distilling action of a current of gas, and then heated in air to revivify it.

M. L. Chappell[45] regenerates spent hydrous magnesium silicate by treating it with acetone, alcohol and petroleum containing a small quantity of sulphuric acid.

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[38] U.S.P. 1,549,469.
[39] U.S.P. 1,550,523.
[40] U.S.P. 1,550,523.
[41] U.S.P. 1,551,806.
[42] U.S.P. 1,538,287.
[43] U.S.P. 1,558,862-3.
[44] U.S.P. 1,562,550
[45] U.S.P. 1,562,868.

A process for recovering spent litharge for use in the "doctor" treatment of light distillates was patented by A. Kinsel[46] who treats the lead sulphide with sludge acid, separates the lead sulphate by filtration and dissolves it in caustic soda.

Developments in American Petroleum Refining.

By Benjamin T. Brooks, Ph.D., F.C.S.

Perhaps petroleum technologists and engineers ordinarily are not supposed to concern themselves with the economics of the petroleum industry, but to leave such questions to others. However to attempt to review the outstanding recent technical charges in the industry without some reference to their bearings on the economics of the industry would be to leave all perspective out of the picture.

Since the manufacture of gasoline has become the paramount concern of industry, those technical developments which have to do with this commodity will be noted first. The last year or two have witnessed improvements in the art of cracking which are of the utmost economic importance. Only a few years ago, after about ten years operation of cracking processes, it may have seemed that the industry had settled down to a standard method of operation; almost every conceivable improvement seemed to have been patented, and no important advances seem to have been expected. The pioneer Burton shell still was in part superseded by the Burton tube type of still, with aerial reflex condensers of various forms, although many Burton shell stills are yet in operation. This view is apparently reflected in the number of Burton stills, of both types, installed in American refineries. Last year there were approximately 1700 Burton stills in American refineries, most of them operating at capacity, some having been installed as recently as 1923. This number of Burton stills of both types represents about 70 per cent. of the total number of cracking units in American refineries. The operation of these stills has frequently been described. In the meantime other processes, particularly the Dubbs, Holmes-Manley and Cross processes, were undergoing rapid development.

The Burton, Holmes-Manley and Cross processes are operated on distillate charging stocks, the Dubbs on either distillates or

[46] U.S.P. 1,525,301.

heavy residual oils. The Cross process apparently requires a clean distillate charging stock of about 30 to 36° A.P.I. gravity; the Holmes-Manley process which has recently been installed at Whiting, Indiana, the original home of the Burton process, is much more flexible in this respect, operating on composite distillates of about 18 to 38° A.P.I. gravity, including heavy distillates from naphthenic oils such as the Gulf Coast oils. The reaction chambers in the Holmes-Manley process are heated about the middle, and are provided with a rotating scraper to remove the coke from the side walls and permit it to collect in the unheated cone bottom of the chamber; the Dubbs reaction chambers are heavily insulated but not externally heated, have no internal scraper and are operated until the chambers are nearly full of coke before shutting down for cleaning, thus permitting the cracking of heavy oils yielding relatively much coke and also the so-called non-residuum type of operation producing only cracked distillate, gas and coke. The tube and tank process of the Standard Oil Company of New Jersey is also said to operate on heavy oils, although the plants of this company are equipped with 206 Burton stills and 10 tube and tank units.[1]

The significance of this situation was frankly stated by Mr. Walter C. Teagle, President of the Standard Oil Company of New Jersey, in a hearing before the Federal Oil Conservation Board in February, 1926. "Since its inception, the petroleum industry has passed through three closely inter-related phases, in the first two of which the value of a barrel of crude has been determined practically by the price that the public paid for a single product. In the early history crude derived its value from its kerosene content." Kerosene gave way to gasoline as the dominating factor, thus distinguishing the second phase, noted by Mr. Teagle but "the price realised for the by-product, fuel oil, continued to be merely incidental." The third phase, as described by him, is characterised by the cracking of fuel oil; "The inventive energy of the industry which has been continously engaged on the problem of increasing the yield of the major product was rewarded, in 1912, by the commercial utilisation of the cracking still which, for the first time, produced a major product from a source other than crude. This early invention and the various processeses which came into existence during the next few years, while representing enormous strides in the science of refining, were limited to the cracking of distillates, leaving yet to be discovered the application of cracking to the fuel crudes and those of high sulphur content

[1]Information given by the Standard Oil Company of New Jersey in pending litigation brought by the U.S. Government against this and other companies.

such as California, Mexican and coastal crudes, the production of which in 1922 represented 45·82 per cent. of the total supplies. The price differential between gasoline and the fuel oil value of these fuel and high sulphur crudes was the incentive for the further development of cracking processes which have been perfected within the past two or three years, and the industry from them. Every grade of crude produced is now a potential source of gasoline."

The situation indicated above will undoubtedly cause these hitherto relatively low-priced crudes to be sought as cracking stock, more and more, as suitable equipment is installed to handle such oils.

As regards consumption of gasoline, probably the most interesting development has been the very widespread introduction of large motor buses, and it has been estimated that the 70,000 buses in daily use in the United States consume as much gasoline as 700,000 ordinary automobiles. The number of commercial trucks has also increased considerably, the number now in use in the United States being about 2,500,000.

Recent Improvements in Cracking Processes.

The Cross process has combined two furnaces and two reaction chambers into a combined unit, or double unit, having a daily throughput of 1600 to 2000 bbls. per calendar day making 27 per cent. to 33 per cent. gasoline. The reaction chambers built for the Cross installation of the Atlantic Refining Company are 45 feet long by 52 inches inside diameter and 4 inch wall thickness, the forging weighing 60 tons.

The Dubbs process has increased the daily throughput by forced hot oil circulation, by increasing the number of tubes in the heating furnace from 50 tubes in the former standard unit to 62 tubes in the same size of furnace, and the units recently installed by the Marland Refining Company have 90 tubes per unit and a daily throughput of about 1600 bbls. per stream day; the largest Dubbs units yet built have 120 five-inch tubes per unit and a daily throughput of 2400 bbls. per stream day, making about 40 per cent. gasoline from heavy California fuel oil. The operating cycle of the Dubbs units has been increased by enlarging the reaction chambers, the Marland units having two chambers, 10 feet by 40 feet, for each unit.

The Holmes-Manley process, which also employs forced hot oil recycling under the full operating pressure of the system, has a throughput of about 1200 bbls. per calendar day. The Texas Company, which operates the Holmes-Manley process, has perfected

the design of bubble towers used in connection with the cracking units, these towers being under the full operating pressure of the system so that the reflux from the bottom of the bubble tower is returned to the heating furnace at a temperature of 700–750° F., and the fresh charging stock is preheated in the dephlegnator, above the bubble tower, to about 600° F. For the successful operation of such bubble towers to make end point gasoline, it is important to maintain constant temperatures in the oil heating system. This is done in the Holmes-Manley units by electrical control devices regulating the gas fuel burned in the heating furnace.

The Holmes-Manley units could undoubtedly be operated at a much higher daily throughput, but by the preferred method of operation, with the oil at 800–845° F. leaving the furnace and about 760° in the last reaction chamber, end point gasoline of satisfactory colour is produced by the cracking unit. This gasoline is refined by treating with dilute sulphuric acid, about 60 per cent. strength and sodium plumbite, and is not redistilled after treating.

The coke produced in cracking operations, being much more friable than the coke produced in old fashioned coking stills, was formerly allowed to accumulate in great dumps, but this is finding increased favour as a fuel and one bricquetting process makes an excellent, firm bricquette from such coke, without a binder. The use of such coke in gas producers also appears to be advantageous, the coke being practically free from ash.

The preheating of the air used in the heating furnace has become quite common and the reduction of extreme furnace temperatures by recirculating part of the flue gases, has proven of value in prolonging the life of the heating tubes in the hottest part of the furnace.

The use of bubble towers under pressure, as a part of cracking units of various types, has been mentioned. The use of such equipment, properly designed and operated, is becoming quite general in the distillation of crudes and in re-running pressure distillates. It is difficult to understand the reason for the tardy introduction of such apparatus into American petroleum refineries. The increased yields of gasoline obtainable by this means as compared with the best former practice, have been estimated to be at least 2 per cent. for the heavier crudes and averaging 4 per cent. for the lighter crudes.[2] One reason doubtless lies in the very accurate temperature and feed controls necessary in such systems as compared with former practice.

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[2] W. C. Miller, "Petroleum Development Technology in 1925," p. 391.

Quality of Gasoline.

Prevailing opinion regarding quality of gasoline has undergone considerable revision. The work initiated several years ago by Ricardo in England and Midgely and Boyd in America on the relative anti-knock value of motor fuels and the actual performance of motor fuels in typical engines, has been largely responsible for these revisions of opinion. It is now generally recognised that cracked gasolines are generally much better, from an anti-knock standpoint, than straight run paraffin gasolines, although the straight run naphthenic gasolines from certain California oils are also recognised to be valuable in this respect. Colour, as a criterion of quality, has been dropped from U.S. Government and American Society of Testing Materials specifications. In cracking processes for making gasoline therefore it would seem desirable to make cracked gasoline as highly unsaturated as possible, quite reversing prevailing earlier ideas in this respect. In fact the past year has seen the installation of several vapour phase—atmospheric pressure cracking plants, which yield a very highly unsaturated gasoline, which is being blended with other gasolines to increase the anti-knock value. The only difficulty or objection to the use of very lightly refined cracked gasolines or blends containing vapour phase gasoline appears to be the tendency of such gasolines to form gummy or resinous deposits on oxidation by air. The widest divergence of opinion exists with respect to the permissible amount of gum as shown by the copper dish test, and there is also general dissatisfaction with the accuracy and significance of the evaporation tests for gum, in motor fuels.

Gum formation by air oxidation is a general property of all unsaturated or olefinic hydrocarbons, but at very different rates for different types of hydrocarbons. It is now generally known that, in ordinary cracked gasolines, the substances which are responsible for rapid or excessive gum formation are probably diolefines, that they are present usually in very small proportions and are very readily removed or polymerised. The method of refining such gasolines with dilute sulphuric acid has accordingly become quite general in the last year or two. Also the method of refining cracked gasolines as produced by passing the hot vapours through a column of Fullers' earth, as developed by T. T. Gray, is being successfully operated in several American refineries. The polymerising action of the Fullers' earth improves the colour and greatly decreases the tendency to form gum. Fullers' earth alone however is not effective in removing sulphur, but favourable results have been reported from the admixture of copper oxide or finely divided copper with the Fullers' earth.

The distribution and sale of "ethyl gasoline" containing tetraethyl lead has been resumed, following an investigation by the United States Surgeon-General as to the possible hazards involved in the widespread use of such motor fuel. Considerable publicity was given to several fatal cases of poisoning in connection with the manufacture of tetraethyl lead. The company chiefly concerned promptly suspended the manufacture and distribution of ethyl gasoline and frankly rested their case with the Surgeon-General. After due investigation and failure to find a case of lead poisoning from handling the gasoline blend, the U.S. Public Health Service proposed certain regulations for the handling of the product, which regulations are being followed in the renewed distribution of ethyl gasoline.

In connection with vapour phase cracking of gas oil to make a highly unsaturated gasoline of high anti-knock value, about equivalent to benzol in this respect, it is of interest to note that one commercial plant has started operations, the major products of manufacture being not only anti-knock gasoline, but a series of solvent alcohols and acetates made from the simpler olefines. The secondary butyl, amyl and hexyl alcohols and the corresponding acetates and tertiary butyl and tertiary amyl alcohols in a high state of purity are manufactured by this plant. Isopropyl alcohol is being manufactured from cracking still gases at two refineries, but the commercial utilisation of this alcohol is reported not to have reached very large proportions, and to do so will probably have to compete successfully with ethyl alcohol. On the other hand the manufacture of ethylene glycol from ethylene has attained relatively large industrial importance, the purest product being used for dinitro glycol as a constitutent in nitro glycerine explosives, and the less pure material for winter use in automobile radiators to prevent freezing. The same company which has developed this use of ethylene has recently introduced glycol mono-ethyl ether as a solvent for cellulose esters[3] and also manufactures ethylene dichloride, ethylene oxide, propylene chlorohydrin and glycol in commercial quantities.

Refining Processes.

The method of refining cracked gasoline, as produced in the vapour phase, has been mentioned above. The subsequent "sweetening" is accomplished by hypochlorite or sodium plumbite solutions. The use of hypochlorite in the United States has found its greatest application in the sweetening of natural gas

[3] J. G. Davidson, *Journ. Ind. Eng. Chem.* **18**, 669 (1926).

gasoline [4] and straight run gasolines which contain little or no elementary sulphur, in which cases free sulphur must be added to the plumbite treatment, usually with the result that the final gasoline is slightly corrosive to copper.

The industry is getting farther and farther away from the universal use of concentrated sulphuric acid. The liquid sulphur dioxide process of Edeleanu is being used in California for refining kerosenes having large proportions of aromatic hydrocarbons, where units have been installed having capacities sufficient to treat 1500 bbls. per day.

The lead sulphide precipitated from sodium plumbite solutions is recovered, according to the patent of A. Kinsel,[5] by digesting it with recovered sulphuric acid thus converting it to lead sulphate, which is filtered, washed and used again in the preparation of fresh plumbite solution.

The open top " agitator " for refining light oils, has been rapidly superseded by closed mixing systems usually of the orifice mixer type, thus eliminating the vapour losses incident to the old procedure; the rapid and thorough mixing, as of gasoline and acid, has also reduced the amount of acid required, with a corresponding reduction of acid tar and polymerisation loss, at least in cases where concentrated acid is used.

The separation of amorphous wax by centrifugal force, although not a development of the past year only, has established itself as one of the processes of major importance to a modern refinery. The product thus separated is an attractive material for research directed to its utilisation.

Together with the decreased consumption of sulphuric acid, as noted above, in various refinery processes, there has been marked progress in the recovery of sulphuric acid in oil refineries. The vacuum method of concentrating, operating at 26 to 28 inches of vacuum, and at a corresponding lower temperature, avoids much of the decomposition with consequent loss ot acid and air pollution common with the older systems. Another greatly improved system of recovery utilises the Cottrell method of electrical precipitation.

High Vacuum Distillation of Lubricating Oils.

The improvements in the technique of distilling lubricating oils in very high vacuum undoubtedly constitutes one of the outstanding advances in refinery technology in recent years.

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[4] W. G. Hiatt, *Oil and Gas J.*, April 23, 1925; G. W. Reid, *Oil and Gas J.*, June 11, 1925.

[5] U.S. Pat. 1,525,301.

Steinschneider[6] showed that, when distilling such oils in *vacuo*, the lightest or most volatile fraction carried practically all of the malodorous substances and that this fraction darkened in colour on exposure to air. In both the Steinschneider and Schulze systems any uncondensed gases and the most volatile fraction are taken off overhead and the heavier condensates are not contaminated with these malodorous products. Schulze[7] has shown that distillation under absolute pressures as low as 3 to 5 mm. of mercury is commercially feasible and that under these conditions the decomposition is reduced to such a minimum that subsequent refining by acid or Fullers' earth is not necessary, such distillates being very pale in colour, without odour or taste, do not discolour on standing in air, have exceptionally low Conradson carbon values, and, being free from naphthenic or sulphonic acid soaps, show almost perfect de-emulsification. Distillates having viscosities as high as 150 seconds, Saybolt, at 212° F. have been obtained from ordinary still bottoms and from heavy Vinton crude the heaviest distillate had a viscosity of 186 seconds at 210° F.

As compared with early practice Schulze points out that the yields of distillate obtainable at these very low pressures are greatly increased. Thus, a heavy residual oil distilled at 40 mm. absolute pressure, which is probably fairly representative of early practice, yielded 30 per cent. distillate up to 572° F. (330° C.), but the same oil distilled at 5 mm. absolute pressure yielding 94 per cent. distillate up to 572° F. Another characteristic of lubricating oils distilled at 3 to 5 mm. is the narrow range of boiling point and narrow range in the viscosity of the fraction, when redistilled in *vacuo*.

In connection with the noteworthy technical advances made by the industry in recent years, it is significant that many companies have built well equipped experimental laboratories, that some have greatly increased their technical staffs, and that geologists are employed by all of the larger producing companies and that geophysical methods of detecting structures favourable for oil accumulation have demonstrated their usefulness. It is not surprising, therefore, that funds have been given by Mr. John D. Rockefeller and by the Universal Oil Products Company for carrying out researches on strictly scientific problems related to the geology, physics and chemistry of petroleum. An initial fund of $500,000 has been given for this purpose, the fund being administered by the American Petroleum Institute through a special committee of its Directors, with the co-operation of the National Research Council.

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[6] U.S. Pat. 981,953 (1911); *J. Inst. Petr. Tech.* **11**, 514 (1925).
[7] U.S. Pat. 1,448,709 (1925).

Cracking.

By R. Pitkethly.

The thermal decomposition or "cracking" of the by-products of the modern refinery for the production of more valuable motor spirit is no longer an experiment, but has reached a state of industrial importance which may be gauged by the relative proportions of straight run gasoline to cracked spirit now manufactured to meet the demand throughout the world. In the United States of America, where cracking has developed to a greater extent than in any other country, the production of cracked spirit steadily increases, and during last year amounted to practically one-third of the total yield. In the Mid-Continental area the percentage of gasoline, recovered from crude oil distilled, amounted to 42 per cent. Californian refiners are also rapidly increasing the yield of spirit by cracking methods. If cracking plant had not developed and taken an active part in the production of gasoline, last year's figure of 10,692 million gallons would have amounted to 7770 million gallons only, and the requirements of crude oil for the present year will amount to about 830 million barrels, instead of 1300 millions which would be required, without cracking, to meet the needs of the motor vehicles in use to-day.

During the last three years the United States of America produced 144 million barrels of cracked spirit, utilising only distillates, and during 1925 65 million barrels of fuel were cracked as against 30 to 35 million barrels in 1924.

The difference between these figures represents approximately the effect of cracking on the petroleum position, and it may be confidently expected that still greater economies will be obtained as further development proceeds. In Great Britain the consumption of gasoline is of striking dimensions, for in 1920 it amounted to about 190 million gallons and in 1925 to 500 million gallons, due to the rapid increase in motor transport, the number of vehicles increasing by 50 per cent. during the last two years.

The use of cracking plant has therefore of necessity increased, otherwise the supply of motor spirit could not have been maintained to meet the demand, and it is not surprising, with all this activity, that the older established plants have become obsolete or have been improved vastly in design and operation

and numerous patents have been filed to swell the multitude already in existence.

Cracking and the production of anti-detonation fuel are amongst the most important problems affecting the petroleum industry and have also become associated, for it is claimed that cracked spirit will stand a higher compression in the motor engine than straight run gasoline, and certain processes are being developed for the direct production of spirit which will eliminate knocking.

C. P. Talman[1] claims such a process which is apparently of the vapour phase type, as the process consists, essentially, of subjecting oil vapours to the action of heated gas; thus the heat is applied internally instead of through metal walls. A considerable amount of spirit is still made by the Burton process, but modern units in operation or under construction are almost entirely of the Dubbs, Cross, Holmes-Manley tank and tube, or Jenkins type of plant, and the improvement in detail and operation of these is remarkable. It may be predicted that a practically continuous process will be possible in the near future, for it is stated that a Holmes-Manley plant created a record by running for 63 days without interruption. This indicates the progress made towards the elimination of coke, which has been the principal obstacle against the successful operation of all cracking plant wherein heat is applied through metal surfaces. Development has been made mostly with liquid phase processes, but the search for anti-detonation spirit may resuscitate the vapour phase type of apparatus.

Much work has been done of an experimental nature to solve the problems which still confront the cracking chemist. The refining of the cracked product and separation of its constituents require much investigation, but Gray's[2] vapour phase process, Brook's[3] pressure distillation and Remfrey's[4] bauxite method appear to be steps in the right direction, as far as the commercial purification of cracked spirit is concerned. For the sake of economy the initial refining of cracked spirit should take place within the cracking plant in order to produce it in a condition similar to straight run gasoline, and requiring only the usual treatment to render it marketable.

The deficiency of low boiling fractions usual in cracked spirit has been overcome by blending it with natural gasoline and the blend behaves satisfactorily in the automobile engine, particularly

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[1] *Mining J.*, July, 1926.
[2] *Journ. Inst. Petr. Techn.*, 1925, **11**, 21A.
[3] *Journ. Inst. Petr. Techn.*, 1925, **11**, 186A.
[4] B.P. 212,500; *Journ. Inst. Petr. Techn.*, 1925, **11**, 51, 365.

when the blend contains products of Russian or Californian oils which increase the anti-knocking efficiency.

The analysis of cracked spirit and of motor fuels generally, particularly the determination of their paraffin, olefin, naphthene and aromatic compounds, has been the subject of much discussion and investigation recently, for it is generally accepted that the behaviour of a spirit in the engine is largely a function of its chemical composition. W. N. Hoyte[5] recommends the use of the refractometer for the determination of the aromatic compounds as there is a marked difference between the refractive indices of the aromatic compounds and of the other hydrocarbons occurring in motor fuel, and the results obtained by this method compare well with the aniline point test.

The U.S. Bureau of Mines[6] have developed an analytical method for the determination of the gum-forming substances in cracked gasoline.

M. B. Cooke[7] has devised a steam-heated oven also for the determination of gummy substances as results are liable to be erroneous on account of oxidation, when evaporation takes place in the atmosphere. The method gives more consistent results than obtained by open evaporation. W. R. Ormandy and E. C. Craven[8] discuss the determination of the unsaturated hydrocarbons in motor spirit. It is recognised that the ease in starting and anti-detonating value depend on the proportion of paraffin, aromatic and naphthene hydrocarbons present, and it is necessary to separate the unsaturated compounds before the others can be determined. It is some of the latter which give rise to the sticky resins in cracked spirit, but such of the mono-olefins which have been prepared in a pure state appear to be clean liquids suitable for motor fuel. Spirits have been obtained, having a high bromine value, which do not deposit gum on standing. None of the methods which have been devised for the determination of unsaturated hydrocarbons in motor spirit appears to be satisfactory, and the authors do not claim to offer a solution to the problem, but they compare the bromine absorption by Hanus' method with absorption in 80 per cent. sulphuric acid and determination of the aromatic compounds by the change in aniline point before and after treatment with 98 per cent. H_2SO_4. It appears that the bromine value is liable to be high, and the effect of washing with 80 per cent. H_2SO_4 seems to be partly solvent and partly a polymerising action. The assumptions that

[5] *Journ. Inst. Petr. Techn.*, 1925, **11**, 48.
[6] *Ref. Nat. Gas Manuf.*, **4**, 6.
[7] *Petr. Times*, **13**, 973.
[8] *Journ. Inst. Petr. Techn.*, 1925, **11**, 533.

80 per cent. acid removes only olefin compounds and 98 per cent. acid removes the aromatic compounds only and completely, do not appear to be correct. C. N. Houghton and S. Bowman[9] investigate the action of sulphuric acid, of different concentrations, on cracked spirit for the purpose of determining the most effective strength of acid in producing polymerisation of the olefins present. The results indicate that 91 per cent. acid has the greatest effect as far as polymerisation is concerned.

H. Moore and R. B. Hobson[10] have also investigated the composition of cracked spirit derived from a Russian kerosene. The origin accounts for the high naphthene content of the product. Washing with 80 per cent. sulphuric acid repeatedly, removes only part of the unsaturated hydrocarbons present as determined by the iodine value, and a state of equilibrium appears to be reached when only 55 per cent. of the olefins have been absorbed. In order to remove olefins completely it seems necessary to use acid of 90 per cent. strength, but this strength of acid appears to remove a proportion of the aromatic compounds also, therefore an alternative method is suggested wherein a factor, representing the amount of increase in aniline cloud point due to the removal of a known amount of olefins, is used.

It is interesting to note that, in the separate fractions distilled from the original spirit up to 95°, 95°–122°, 122°–150°, the percentage of unsaturated hydrocarbons decreases and the percentage of aromatic hydrocarbons increases as the boiling point rises. F. H. Garner[11], referring to the treatment of cracked spirit with H_2SO_4 suggests that a proportion of the aromatic compounds are removed along with the unsaturated compounds, and quotes Brochet's work[12], who found that normal hexylene reacts with benzene in the presence of sulphuric acid, 93 per cent. strength, giving a yield of 50 per cent. hexylbenzene. It is therefore necessary to ascertain that sulphuric acid, in the concentration used for the removal of olefins, is not only without action on aromatic hydrocarbons but also that it is without action in the presence of olefins.

J. C. Morrell and G. Egloff[13] review past work and investigate the sulphuric acid absorption and iodine value by Hanus' method in the determination of unsaturated compounds. They come to the conclusion that the sulphuric acid method may be used for rapid determination, and if time, temperature and concentration

[9] *Journ. Inst. Petr. Techn.*, 1925, **11**, 583.
[10] *Journ. Inst. Petr. Techn.*, 1925, **11**, 587.
[11] *Journ. Inst. Petr. Techn.*, 1926, **12**, 54, 66.
[12] *Bull. Soc. Chim.*, **9**, 867.
[13] *J. Ind. Eng. Chem.*, **17**, 12, 1259.

factors are maintained constant reliable results may be obtained by the Hanus method; but further study of the mechanism of the reactions is necessary, especially the substitution reactions of the higher unsaturated hydrocarbons. J. S. S. Brame[14] gives additional information regarding the action of sulphuric acid on aromatic compounds in presence of olefins. A cracked spirit obtained from a Russian kerosene cracked in a Cross plant was used, with and without the addition of toluene. With each strength of acid there was a large diminution in the content of toluene. With 85 per cent. acid 30 per cent. of toluene disappeared, and with 88 per cent. acid the loss was over 50 per cent. These results appear to confirm Brochet's statement.[12]

F. G. Niece[15] improves apparatus, in which oil is cracked by bringing it into contact with molten metal, by returning uncondensed gas through a sheath surrounding the oil inlet tube. These tubes are arranged so that they may contract or expand freely. H. C. Wade[16] expands heated oil and water together into a chamber. The vapours produced by the explosive action of the sudden expansion are passed through a cracking coil.

C. W. Thomson and H. C. Beeler[17] mix liquid hydrocarbons with an inert carrier, such as gravel, and pass the mixture through a retort comprising separate heating zones of increasing temperature. The operation is carried out at atmospheric pressure.

W. E. Shore[18] heats oil in the jacket of an internal-combustion engine, which operates a compressor and a mechanical nebulizer. The oil is passed through the compressor jacket, and through a heater which utilizes the heat from the engine exhaust. Hydrogen gas is mixed with the hot oil and the mixture nebulized. It is then returned through the engine exhaust heater. The vapour and hydrogen mixture is further directed through coils, which are heated by the expanding gases from the compressor, then compressed adiabatically and expanded into drums containing heating coils. Progressive condensation follows by passing the vapours into hydrocarbon liquids of various specific gravities to separate the products.

The jacket surrounding the nebulizer is connected in closed circuit with a heater for producing mercury vapour which imparts a high temperature to the expansion chamber of the nebulizer. H. P. Benner[19] provides a cracking still with a corrugated flue

[14] *Journ. Inst. Petr. Techn.*, 1925, **12**, 55, 221.
[15] E.P. 203,339.
[16] U.S.P. 1,530,587.
[17] U.S.P. 1,530,627.
[18] E.P. 231,625.
[19] U.S.P. 1,524,818.

running centrally through it and a flushing nozzle with a number of jets extending into the still circumferentially around the corrugated flue.

The oil, introduced into the still through the jets tends to clean the deposited carbon from the heating tubes.

G. Egloff and H. P. Benner[20] use spirally corrugated heating tubes in the furnace of cracking plant to give greater heating area and increased velocity to the oil.

W. B. Howard[21] passes the vapours from a cracking still through a reflux condenser. The reflux oil is transferred to a second still at a higher temperature and pressure, and the vapours generated are returned to the reflux condenser. In this way the reflux is continuously retreated.

John Hancock[22] emulsifies oil, water and caustic soda by pumping through a whirling nozzle into the emulsifying chamber, then through a specially designed cracking plant consisting of various coils.

The Jenkins cracking process[23] has been improved, and cracked gasoline is refined within the unit to give a water white product.

The Société Anonyme des Petrols[24] propose to dehydrate, distil, and crack by radiant heat directed by parabolic mirrors on a spray of oil. The heating device consists of electrical elements or tubes containing heated fluids placed in the foci of vertical slots of parabolic cross section disposed in the inner wall of a tower, down which the oil is sprayed.

G. F. Forward[25] sprays oil, mixed with water or water vapour, through a retort containing charcoal. A catalyst is mixed with the oil and hydrogen may be supplied.

V. L. Processes and O. D. Lucas[26] spray oil, preheated to about 400° C., into a cracking retort containing a layer of coke which is kept in motion by a conveyor. Carbon is deposited on the coke and periodically removed. This retort is heated to 500° C., and the vapours produced therein pass to a second chamber which is provided with a catalyst and heated to about 500° also. A portion of the cracked gases may be returned to the first retort along with a small proportion of ammonia to supply nascent hydrogen.

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[20] U.S.P. 1,535,655.
[21] U.S.P. 1,535,724.
[22] U.S.P. 1,528,327.
[23] *Petr. Times*, 14, 352.
[24] E.P. 224,497.
[25] E.P. 239,556.
[26] E.P. 244,875.

C. N. Forrest and H. P. Hayden[27] destructively distil hydrocarbons by charging, with them, pieces of refractory material. The porous aggregate progresses through the reaction zone, and is then subjected to a limited counterflow of air. The coke formed by cracking is consumed and the inert carrier restored to its original condition.

L. D. Wyant[28] heats oil to a cracking temperature, and at the same time agitates it to maintain the liberated carbon in suspension. A collector is provided above the level of the oil, and means provided for the separation and discharge of the carbon.

B. T. Brooks[29] manufactures motor spirit by cracking oils under conditions which give a large yield of olefinic products.

E. Blumer[30] cracks continuously in an autoclave filled with molten metal. Inside the autoclave is placed a sheet metal container fitted with sieves at its upper and lower ends and filled with Raschig rings. It has also slits or baffles so that the molten metal may circulate freely within the container and through the annular space between it and the outer vessel. The oil to be cracked is pumped into the inner vessel, and emerges as a fine spray or vapour which passes through the molten material, and is prevented from coming into contact with the hot walls of the autoclave, thus preventing the deposition of carbon.

A. A. F. M. Siegle's[31] apparatus for cracking oils consists of a series of double walled cylindrical drums. The oil passes through the annular space while the flue gases pass through the central tube counter current to the oil flow.

C. M. Alexander[32] sprays heavy oil into a large body of oil maintained at a high temperature and energetically agitated. The cracked oil is circulated through a settling chamber, wherein carbon is deposited and returned to the still.

R. W. Hanna and others[33] obtain a lubricating oil having a green fluorescence by combining an oil stock obtained by cracking a petroleum oil, with a fuel oil base obtained by standard methods.

H. D. Demoulins and F. H. Garner[34] use hypochlorite to disulphurise cracked distillates in the vapour phase. The refining agent may be sprayed into the outlet of a dephlegmator or fractionating tower.

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[27] U.S.P. 1,568,018.
[28] U.S.P. 1,563,818.
[29] U.S.P. 1,563,012.
[30] U.S.P. 1,573,370.
[31] U.S.P. 1,572,691.
[32] U.S.P. 1,568,016.
[33] U.S.P. 1,566,000.
[34] E.P. 216,918.

F. W. Hall[35] claims that the reaction products, both solid and liquid, from the heating of aluminium chloride, carbon and chlorine together, form a suitable agent for the treatment of oils.

G. Egloff and H. P. Benner[36] refine cracked oil by distilling in the presence of hydrochloric acid and finely divided earth.

B. T. Brooks[37] treats cracked gasoline by subjecting it to a heat treatment for a sufficient time at a sufficient temperature to remove by polymerisation the unsaturated hydrocarbons which possess an objectionable odour. The cracked distillate is altered in composition, and the colouring matter does not distil, so that the treated spirit can be refined like straight run gasoline.

A. Mailhe[38] refines and bleaches cracked gasoline with metallic chlorides or by passing the vapours over chlorides at 200° C., followed by soda and water washes.

J. C. Morrell[39] deals with the purification of cracked spirit by the use of sulphuric acid, alkali, lead oxide and water.

J. C. Morrell[40] refines cracked spirit with sodium plumbite in solution of sulphur dioxide.

E. H. Payne and S. A. Montgomery[41] chlorinate the gases from cracking plant at a temperature of 150° in the presence of a porous catalyst such as the solid product obtained by treating high boiling oils with chlorine. The liquid chlorination product boils between 55° and 193°.

The waste of aluminium chloride has been the principal difficulty in the development of the processes using this catalyst, and A. M. McAfee[42] claims a process whereby the oily residues are heated in the presence of air to oxidise the carbon, and thereafter the heating is continued to effect the distillation of the aluminium chloride. Alternatively[43] he boils the residue with heavy oil, and the vapours are cooled to separate the aluminium chloride and heavy oil.

J. C. Morrell and G. Egloff[44] report on the cracking of shale oils from different sources for the production of motor fuels. Analysis of the products indicate high antiknock properties.

In hydrogenation the International Bergen Co.[45] utilize the gases evolved from cracking plant by decomposing them by the

[35] U.S.P. 1,512,420.
[36] U.S.P. 1,535,653.
[37] U.S.P. 1,550,673.
[38] *Comp. rend.*, 181–668.
[39] *Petr. Zeitschrift*, 1926, **6**, 219.
[40] U.S.P. 1,568,904.
[41] U.S.P. 1,520,506.
[42] U.S.P. 1,520,831.
[43] U.S.P. 1,534,130.
[44] *Oil Age*, **23**, 5–44.
[45] E.P. 216,882.

action of heat and return the hydrogen obtained to the cracking vessel.

The relative rates of catalytic hydrogenation of different types of unsaturated compounds have been studied by S. V. Lebeder and others.[46] The rate of absorbtion of hydrogen by an unsaturated compound in the presence of platinum black is a linear function of the time, and the rate is determined by the number of substituents, being greatest for a mono substituted compound, but declines as the number of substituents increases.

G. Stadnikoff and others[47] hydrogenate technical cresol, with the production of 80% toluene. The catalyst is reduced iron and carbon deposited thereon in the primary stage of the process. The presence of sulphur compounds destroys the catalyst by formation of inactive sulphide of iron.

H. I. Waterman[48] continues his experiments on hydrogenation by the Bergius method. Rangoon wax under a pressure of 290 atmos., and at a temperature of 450° C. yields a liquid product. Analysis of the gasoline fractions indicate the presence of pentane, hexane, heptane, octane and nonane. Aromatic hydrocarbons exist only in traces. The gasoline fraction appears to be composed of paraffins with about 10% of olefin compounds.

H. Gault[49] continues the investigation of cracking with particular reference to the behaviour of hexadecane under conditions of thermal decomposition at constant rate of flow but with different lengths of furnace. The yield of gas increases with increase of temperature and increasing furnace length, and the proportion of unsaturated gases increases up to 540°, then deceases; it is greater with a short furnace. The proportion of saturated hydrocarbons decreases up to 615°, then increases; it is greater the longer the furnace.

The liquid product decreases with rise of temperature slowly up to 540°, then rapidly to 750°, where it remains constant. The refractive index increases rapidly with furnace temperature, and the density varies with the refractive index. The proportion of liquid more volatile than hexadecane is very small up to 615°, then rapidly increases, and is greater the longer the furnace.

The solubility in dimethyl sulphate (index of aromatic content) increases with rise of temperature between 685° and 815° and is greater the longer the furnace.

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[46] *J. Chem. Soc.*, **127**, 418–440.
[47] *Brennstoff-Chem.*, 1926, **7**, 7–9.
[48] *Rec. Trav. Chim.*, 1926, **45**, 284–295; *Journ. Inst. Petr. Techn.*, 1926, 12, 42A.
[49] *Les Matieres Grasses*, **205**, 7169.

S. W. Leheder and E. P. Filonenko[50] report on the action of Florida earth on symmetrical and unsymmetrical unsaturated compounds.

A. Williams-Gardner[51] studies the cracking of paraffins, and particularly ethane, with a view to the elucidation of the nature of the chemical changes involved in cracking operations. Ethane shows signs of decomposition at 550° C. Up to 800° conditions appear to favour the formation of liquid products, but above this temperature methane carbon and hydrogen are formed, while below this temperature aromatic compounds are found in the product in appreciable amounts, benzene being one of the chief constituents.

The Bean process[52] described by J. Harris is a cracking process designed for the production of gas, of high calorific value, by the thermal decomposition of heavy oils. A considerable quantity of gasoline, however, is also produced in the process which is operated by passing a mixture of steam and hydrocarbons through a continuous tube. This tube is divided into four sections which operate under automatic temperature control. From the vapour and gas produced gasoline is obtained by compression and absorbtion.

Steam is superheated in the presence of nickel discs which dissociate it into its elements. The oil is treated in the heating coil in presence of the dissociated steam, and the mixed gases are injected into an expansion cylinder. About 25% of the oil treated is recovered as gasoline.

The proper application of heat to tubes and stills, in order to avoid overheating is of great importance in cracking, and A. E. Nash[53] describes a furnace specially designed to promote combustion of the fuel without excessive air. The furnace consists of a long muffle constructed of carborundum tiles wherein practically theoretical combustion conditions are maintained. The carborundum furnace allows the complete mixing of the combustible with air at extremely high temperatures and at the same time lowers the stack temperature. The heat passing through the carborundum tiles as radiant heat is evenly distributed and flame impingement on the tubes or still is eliminated, thus local high temperatures are avoided, although more heat is applied to the oil, while temperature control can be accurate. The use of these furnaces appears to represent an increased efficiency of from

[50] *Ber.*, 1925, **58** [B], 163.
[51] *Fuel*, **10**, 430.
[52] *The Oil Trade*, **16**, 11, 35.
[53] *The Oil Trade*, **17**, 2, 49.

25 to 50%. The heat of convection is utilised by placing a secondary coil in the path of the flue gases.

One of the few vapour phase processes now in operation bears the name of W. G. Leamon.[54] The heating element of the plant consists of a Foster oil heater. The feed, consisting usually of a mixture of reflux from the dephlegmator and raw stock, is passed through a coil heated to a predetermined temperature, thence into a tar drum where heavy unvaporised oil is deposited, and allowed to run out of the system. The vapours are circulated through the heating element, and raised to as high a temperature as possible without decomposition to carbon. From the heater the gases pass into the catalytic chamber thence to heat exchanger, fractionating column and condenser.

The finished product is called Stellarene, and is stated to have an anti-detonation value equivalent to a gasoline benzol blend containing 35% benzol.

F. A. Howard[55] cracks hydrocarbons by subjecting them to the action of mercury vapour at a temperature in the neighbourhood of 380° C. The hydrocarbons are thus heated uniformly.

D. L. Thomas[56] treats cracked spirit at a high temperature and pressure, and at the same time subjects the oil to the action of the silent discharge of a high tension electric current for the purpose of polymerising the unsaturated or gum-forming substances in cracked spirit.

Lubricants.

By HAROLD MOORE, M.Sc.(Tech.), A.Inst.Mech.E.

THE year has shown steady scientific progress in refining technology and in the study of the problems, both practical and theoretical, of lubrication. The nature of the lubricants employed in this country and the source of supply indicate remarkable and far-reaching developments. Probably in no year in the past since the adoption of mineral lubricating oils have such important changes taken place, and although some of these are not strictly technical, the developments may be included under the heading of "Progress of Naphthology."

The types of lubricating oils used in this country have been steadily changing from year to year since pre-war days, and one of

[54] *Oil and Gas J.*, **25**, 7.
[55] U.S.P. 1,586,994.
[56] U.S.P. 1,585,573.

the most noticeable changes has been the increase in the use of bright stocks which have been dewaxed by the Sharples process. Such oils, unknown five years ago, now form an ingredient of a large proportion of the lubricating oils used in this country. These bright stocks range in viscosity from around 120 seconds at 200° F. to 200 seconds at 200° F. (Redwood). During the last two years a considerable change has taken place in the method of operating dewaxing processes in the United States, and naturally the results have been felt in this country. Whereas the Sharples process as originally introduced was used for the removal of wax from filtered cylinder stocks of comparatively high viscosity, the procedure has now been modified, and instead of preparing high flash-point cylinder stocks and subsequently dewaxing, it is found advantageous to prepare a " Long Residuum " or a base oil of comparatively low viscosity and low flash-point, and to dewax this base oil, thus preparing an oil of viscosity from 65 to 90 seconds at 200° F. (Redwood) *i.e.*, a class of oil directly applicable for petrol motor lubrication.

At first sight, this change may not appear to be of any great importance. In practice, however, it has several important advantages over the older bright stock processes. By the latter processes the cylinder oil portion of the crude was finished at an extremely low cold test—in the region of from 15° to 20° F., but the distillates obtained during the manufacture of the stock were not centrifugally dewaxed and therefore possessed a higher cold test (28° to 32° F.). When these two oils were blended back to form a heavy bodied lubricating oil, the resulting cold test was considerably higher than the cold test of the bright stock. By the older process, comparatively high distillation temperatures were employed in the preparation of bright stock, and these occasion a slight cracking of the oil, the result being that when the finished bright stock and the distillate obtained are blended together it is found that the viscosity of the mixture is considerably lower than the viscosity obtained by working the same portion of the crude oil through the Long Residuum process without extracting the distillate. In the Long Residuum process the residue is left in the stills at a much lower temperature than if a cylinder stock were prepared, and possesses a closed flash-point from 360—450° F. as against the flash-point of 460—550° F. possessed by the bright stock. The Long Residuum process has now largely superseded the older bright stock process, both in working Pennsylvanian and Mid-Continental crudes, and the oils obtained are remarkable for their sweetness and excellent demulsification properties. The specific gravity of the oil obtainable by the Long Residuum process is slightly lower than that of a corresponding blend from Bright Stock and Neutral.

The centrifugal dewaxing process has also been modified, in that whereas in the past it has been mainly confined to the working of residua from which the asphalt has been precipitated by acid treatment, it is now employed in certain cases on distillates. The distillate process is used on occasions when the crude is of such a nature that the acid precipitation of the asphalt would result in extremely high losses, and therefore instead of precipitating the asphalt it is found to give an economic advantage if the oil be distilled under high vacuum with a plentiful supply of steam, a residue of hard asphalt remaining in the stills. Lubricating oil distillates can be collected in one large fraction, dewaxed by the centrifugal process, and afterwards redistilled to meet market requirements.

The development of the contact clay filtration process has resulted in a slight change in the nature of the lubricants received in this country. Whereas a year ago the bulk of the pale and red oils was prepared by acid and soda washing, these oils are now prepared by the contact clay process, generally giving paler colours and better demulsification tests. In the past the clays employed have been generally acid-treated, but very effective clays are now obtainable in the natural state, *i.e.*, the clay does not require acid treatment before use.

On account of trouble in obtaining oils of satisfactory demulsification test for use as turbine lubricants, several oil suppliers in this country are installing small contact clay plants for treating finished lubricants. The refining of lubricating oils in this country shows enormous development. Whereas a year ago practically no lubricants were actually being prepared in this country, large quantities of Venezuelan reds and pales are now being worked on the Thames, and Persian oils are being offered from Llandarcy. The lubricants obtainable from Persian oil possess physical characteristics very similar to those of American oils of Mid-Continental base. The specific gravity is midway between those of Pennsylvanian and Asphaltic base oils, whilst the flash-point is approximately that of Pennsylvanian oil.

Apart from the activities of the Shell and Anglo-Persian Companies a large amount of plant is being installed by other interests, and there is every indication that in a short time the lubricating oil equipment of this country will be of such dimensions as to be capable of supplying the major portion of the lubricating oil required in this country. A certain amount of Hardstoft oil is being refined and actually marketed as lubricant.

This refining activity has naturally had considerable influence on the prices of lubricants, resulting in heavy reduction in price

of those lubricants which have to meet the competition of the home manufactured oils.

The oil from the Russian fields is regaining its pre-war popularity, and recently the quality has slightly altered, batches of Russian lubricating oil now arriving with slightly lower specific gravity and slightly higher flash-point than in the past. This probably indicates a slight alteration in the nature of the crude being used.

Bachmann and Brieger[1], suggest a novel method of testing the oiliness of lubricants. A 50 per cent. solution of the lubricant was dissolved in benzene and the amount of heat generated by adding this mixture to 100 grams of finely divided copper was determined. It was decided that the oiliness was proportional to the heat of wetting. The solvent benzene has a low heat of wetting and therefore does not affect the results very much.

Experiments gave the following figures :—

Castor oil	12·1	cals.
Linseed oil	13·8	,,
Liquid paraffin	3.85	,,
Kerosene alone	5·7	,,
Kerosene with the addition of 1% oleic acid ..	21·3	,,

The importance of stability in mineral lubricating oils has received more attention in recent investigations, and there is no doubt that some standard test for measuring the stability, particularly as regards oxidation, is desirable. The specification drawn out by the Air Board makes use of an oxidation test in which the oil is heated for 12 hours at a temperature of 200° C., during which period air is blown through the oil. The coke and viscosity are determined before and after, the increase in these tests being invariably proportional to the stability of the oil.

The stability tests used for transformer oils leave much to be desired, even when used to measure the stability of insulating oils, and are still less satisfactory as tests for the valuation of lubricating oils. Wilson and Allibone[2] point out that stability may be classified under two headings—resistance to oxidation and resistance towards decomposition at high temperatures. The two tests which have become standardised for this purpose are the oxidation or sludging test and the Conradson coke test. Providing the dimensions of the apparatus used for the Conradson coke test are standardised concordant results can be obtained, but as the existing specification does not ensure this, the value and significance of the test remain to some extent uncertain. Wilson and Allibone also criticise the standard sludge test as a measure of stability toward oxygen, and

[1] *Koll. Zeit.*, 1925, **36**, 142-154.
[2] *Journ. Inst. Petr. Techn.*, 1925, Vol. 11, 49, 177.

in their own experiments they have reduced the period of oxidation from 45 to 6 hours and have increased the temperature from 150° to 170° C., using oxygen instead of air. They point out that small quantities of substances such as powdered metals, carbon and dust give very greatly increased readings in this test.

A sludge produced in a turbine has been investigated by Salathe[3] and was found to be an emulsion of water and oil with absorbed salts. The separation of water was effected with petroleum ether. The aqueous layer contained copper and calcium salts and sulphuric acid. The dry sludge had a high saponification number, indicating the presence of acids, esters and soaps, and contained lower fatty acids, naphthenic acids and acetaldehyde. Doubtless the sulphates and sulphuric acid had originated from sodium salts or organic sulphonic acids left in the lubricant in the refining process.

The testing of transformer oils for stability has been the subject of numerous papers, the Michie test being further criticised. Von der Heyden and Typke[4] point out that the testing methods adopted in Germany, Sweden and elsewhere for transformer oils depend largely on the determination of the products of decomposition in the oil. The precipitated sludge only contributes slightly to the "tar value." They propose a test consisting of heating 150 grams of oil in an Erlenmeyer flask to 120° C. for 70 hours, any oil depositing sludge being rejected as unsuitable. In case no sludge is deposited the tar value is determined on 50 grams of the oil by mixing with three times its volume of normal benzene and allowing to stand for 12 hours. If sludge is formed the oil is rejected. In the case of dark oils, the sludge is detected by filtration.

Staeger[5] reviews the properties and composition of transformer oils and criticises the methods of testing advocated by various authorities. On exposing oils for long periods (some tests being as long as 1000 hours) he finds that copper is active as promoting decomposition. He considers the temperature employed in the Michie test too high to give results which are directly interpretable into actual service results, and prefers a test in which the oil is heated in a copper beaker for three hours at 112° C., after which the sludge is determined gravimetrically.

Tytschinin and N. Butkov[6] have examined sludges from transformers and find them to consist of salts of organic acids, the acids

[3] *Ind. and Eng. Chem.*, **18**, p. 415.
[4] *Petroleum*, 1925, **21**, 1553-4.
[5] *Ind. and Eng. Chem.*, 1925, **17**, 1272-1275.
[6] *Neftjanoe Slancevoe Chozjajstvo*, 1924, **7**, 341-349.

varying from C_{11} to C_{22}. They find that both copper and lead accelerate oxidation, particularly the latter. Zinc, tin and iron have no catalytic action. Sludge differs considerably with different oils, and they advocate a special test of their own involving heating for 70 hours at a temperature of 120° C. whilst passing a current of oxygen through the oil. Tytschinin and N. Butkov[7] observe that the effect of refining transformer oils with Florida earth increases the liability to oxidation. Refining with Oleum has a similar only more pronounced action.

Several papers have been written on the subject of crank-case dilution. These papers mainly originate from the United States, where the crank-case dilution problem in automobile engines is much more serious than in this country, on account of the heavy distillation range of the fuel used. Barnard[8] has made determinations of the relation between crank-case dilution and wear of the working parts. A medium motor oil of 285 Saybolt at 100° F. was employed as lubricant. The percentage dilution was deduced by comparison of the viscosity of the crank-case oil with a curve obtained by viscosity determinations on samples of original oil diluted with kerosene. The wear was determined by estimating the amount of iron in the used oil. Tests were made on five cars and also on two test bed engines fitted with dynamometers. With the road tests it was found under ordinary conditions that the wear estimated from the oil analysis is inconclusive owing to settling of metallic particles. The tests do, however, indicate increase of wear with dilution. Dynamometer tests showed that the rate of wear increased more rapidly than the percentage of dilution, particularly when the dilution exceeded 10—15 per cent.

Various systems for the recovery of crank-case oil have been put forward. Rhodes and Hayon[9] tested the action of various alkaline solutions—calcium chloride and sodium silicate—on crank-case oils. The most satisfactory method was found to be a treatment with sodium silicate solution followed by passing through a high-speed centrifuge. This clarified the oil, and the light products were subsequently removed by steam distillation.

Brunt and Millar[10] recommend a brief agitation with 2·5% of sodium silicate solution. Manganese resinate and a trace of stearic acid are added to the oil to assist in separating the sludge. If after agitation the oil is poured on to a layer of water, precipitated

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[7] *Chem. Zeitung*, 1925, 96 II., 253 (cf. B., 1925, 161.)
[8] *Ind. und Eng. Chem.*, 17, 278.
[9] *Ibid.*, 17, 25, 1925.
[10] *Ibid.* 17, 417.

matter will sink into the water, leaving a clean oil-water interface. Neutralisation of any acid is effected by the alkali of the sodium silicate. Rectification of the clarified oil is carried out by passing it in thin layers over electrically-heated inclined plates in a current of air. A continuous apparatus embodying this process is described.

Flowers, MacBerty and Reamer[11] use trisodium phosphate solution as an agent. After treatment with the reagent the oil is passed through a centrifugal oil purifier and heater and an evaporating tower.

The prevention of explosion in air compressors has been the subject of a paper by Parrish and Whaley[12]. The authors have investigated the subject of explosions in the receivers connected to air compressors, and find that the explosion takes place only when a stratification of oil and vapour can take place in a stagnant portion of the receiver. They have designed a system whereby the air leaving the receiver is withdrawn through a tube within a few millimetres of the lowest possible level, and any air flowing from the pump or compressor to the air system is passed entirely from the top to the bottom of the tank before it can leave. This effectually sweeps all gases and vapours from the receiver and keeps it full of fresh air, only a minute amount of oil and vapours being allowed to collect and stratify. The appliance has been found quite satisfactory over extended trials.

Robert Sulzer[13] has given the results of experiments in determining the temperature variation and heat stresses in Diesel engines. Although the investigations were not primarily connected with lubrication, the results obtained are of the greatest interest as to their bearing on the lubrication of internal combustion engines.

In the past widely varying estimates have been made as to the temperatures encountered in the actual working parts of internal combustion engines. Sulzer has actually determined the temperatures of the more important parts of a 1350 B.H.P. 2-stroke Diesel engine whilst in operation. Thermocouples were fixed in various positions on the cylinder wall, in the piston head, and in the top piston ring, recording apparatus was connected to the galvanometers, and the variation in temperature during different portions of the cycle was measured. The results are given graphically. On the cylinder wall the temperature was measured from close to the inner wall and also at depths of 1, 2, 3, 4, and 5 millimetres,

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[11] *Ind. and Eng. Chem.* 17, 481.
[12] *Journ. Inst. Petr. Techn.*, 1925, 11, 50, 305.
[13] *Engineer*, 1926, April 2nd and 9th, 391-392 and 420-421.

and it was found that close to the inner skin of the inner wall the mean temperature was about 240° C and that during the cycle the temperatures varied from 14° C. above to 8° below the mean. As the distance from the inner surface of the cylinder wall becomes greater the variation in temperature during the cycle is less marked and at 5 millimetres from the inner wall the variation in temperature during different portions of the cycle is very small.

The curves not only show variation in temperature during the cycle but also show temperature variation lag at various depths in the cylinder wall.

The temperature of the centre of the piston head, when the engine is operating at half load, varies from about 157° to 163°C. The hottest part of the head is not in the centre, but half way between the centre and the edge of the piston head. The half load temperature at this point varies from 197° C. to 211° C. The top piston ring gives a maximum temperature of about 126° C. at three-quarter load, the measurements being taken half a millimetre beneath the rubbing surface. At 1·5 millimetres beneath the rubbing surface, under the same conditions, the temperature is slightly lower, but the variation in temperature during the cycle is about 3°, whereas closer to the rubbing surface the variation is about 10°. Particulars are also given of the increase in temperature of various working parts of the engine when it is started up from cold. The tension and pressure stresses caused in various parts of the metal may be calculated from these figures.

A point of considerable interest that arises in these results is that they show that the maximum temperature of the working parts of a Diesel engine is lower than those encountered in a high superheat steam engine. This is contrary to many statements which have hitherto been made.

The Diesel Engine Users' Association have for the last few years been compiling statistics as to the cost of running Diesel engines. Figures have been taken from a large number of installations. In their report one finds the consumption of lubricating oil for a year's working for the whole of these installations works out at 0·0017 gallons per electrical unit. The Diesel Engine Users' Association have now issued a specification which their members may employ in buying lubricating oil. Two grades of oil are specified, one slightly heavier than the other. The lighter grade is recommended for high speed engines and the heavier grade for engines operating at speeds below 240 r.p.m. The requirements of the specification are very rigid and although comparatively few tests are specified the figures given are such as only to allow high grade Pennsylvanian oils to clear the specification. No tolerance is

allowed, and the methods of test are those of the Institution of Petroleum Technologists. The specification is as follows :—

For engines operating at 100-240 *r.p.m.*—	
Specific gravity	Not exceeding 0·885 at 60° F.
Closed flash point	Not below 400° F.
Viscosity Redwood	Not exceeding 1250 secs. at 70° F.
	Not less than 56 secs. at 200° F.
Cold test	Not higher than 35° F.
Appearance (colour by transmitted light)	Clear red.
Engines operating at speeds over 240 *r.p.m.*— ..	
Specific gravity	Not exceeding 0·882 at 60° F.
Closed flash point	Not below 400° F.
Viscosity Redwood	Not exceeding 700 secs. at 70° F.
	Not less than 50 secs. at 200° F.
Cold test	Not higher than 35° F.
Colour by transmitted light ..	Clear red.

The oil must be a straight mineral oil.

The valuation of lubricating oils for automobile use was the subject of a paper by Moore, read before the Commercial Motor Users' Association[14]. It is stated that the minimum number of tests for the commercial valuation of motor spirits includes specific gravity, viscosity Redwood at 100° F., 140° F. and 200° F., flash point, coke test, cold test and appearance. Emphasis is laid on the importance of the viscosity-temperature curve and examples of the readings of oils of various bases are given.

[14] *Journ. Inst. Petr. Techn.*, 1925, 11, 53.

Special Products.

By F. G. P. Remfry, B.A., D.Sc., A.I.C.

Activated Carbon.—The preparation of activated charcoal by new methods has been the subject of several patents during the last year. Dorsey[1] activates coconut shells, wood fibres, etc. by first partially distilling off the hydrocarbons at 700° C. and removing the remainder by steam or other gas capable of preferentially oxidising them.

The Badische Anilin and Soda Fabrik[2] make active charcoal suitable for removal of H_2S from gases by blowing gases from the combustion of "blue gas" over carbonaceous material (impregnated or not with salts, such as $ZnCl_2$) until the temperature reaches 800° C., when steam is also applied.

[1] U.S.P. 1,517,543.
[2] E.P. 216,761-23.

Bonnard[3] incorporates moist sawdust with lime, heats this to 1000° C. to remove CO, and activates the charcoal and removes the lime by HCl or HNO_3.

Muller-Clemm[4] impregnates cork, wood, etc., with K sulphide and heats to incandescence in absence of air, the material is then thrown into water, leached and treated with HCl. Ruff and Hohlfeld[5], continuing their work on the mechanism of adsorption by charcoal, consider that this is similar to the formation of complex molecules, the active carbon atom acting as the central molecule of the complex. Activity is due to a definite grouping of carbon atoms at the surface of the charcoal and the total quantity of material adsorbed is independent of the concentration but dependent on the number of active centres and not on the total surface or weight of adsorbent employed. Temperature is an important factor.

The evaluation of activated charcoal by means of the adsorption of methylene blue has been further examined by Mecklenburg,[6] who measured the time required to remove all colour by weighed quantities of carbon from 20 c.c. of a 0·15 per cent. solution of the blue. The relation between the time, Z, required to decolourise the solution and the quantity, M, of the carbon used is expressed by $(M-a)\ Z=K$ where " a " is the quantity of carbon just sufficient to decolourise the solution in infinite time, and K is a time constant. The quantity " a " decreases with increase of the total surface of the particles of carbon.

The difference in adsorptive capacity between various forms of amorphous carbon have been studied by Nellensteyn[7] who found that ash-free natural graphite would not adsorb methylene blue but took up noticeable quantities of succinic acid, whilst diamond powder adsorbed small amounts of methylene blue but no succinic acid. The varying and sometimes selective action of different sorts of amorphous carbon is explained by considering that their carbon structure is either like that of graphite (aromatic), or of diamond (aliphatic) and that so-called inactive carbon is mostly due to impurities covering the surface.

Iliin,[8] assuming the electric nature of adsorption forces, calculated the adsorption capacity at high and low temperatures and found that with equal heats of adsorption the amounts of adsorbed gases on different adsorbents, such as charcoal and mica, are the

[3] U.S.P. 1,520,801.
[4] E.P. 224,521.
[5] *Kolloid Z.* **36**, 23.
[6] *Kolloid Z.*, Special No., April, 1925, 132.
[7] *Chem. Weekblad* **22**, 291.
[8] *Z. Physik* **33**, 435.

same, from which he deduces that adsorption is not a specific phenomena. The adsorbing surface of 1 g. of charcoal is calculated to be theoretically 105 sq. cms. The surface energy of the adsorbent, which is proportional to the heat of adsorption, is taken as a measure of the adsorption capacity.

A review of the present knowledge of adsorption by activated charcoal is given by Abonnenc.[9]

In order to prevent spontaneous oxidation of substances adsorbed on activated charcoal by the contained oxygen Berl[10] impregnates the charcoal with very small amounts of tin compounds, sugar, glycerol, mannitol or other polyhydric alcohols.

McKee and Horton[11] have shown that alkali impregnated chars possess properties akin to colloids and are capable of removing metals from solution, but acid treatment converts them to ordinary decolourising carbons. To restore their former properties a treatment with alkali at 850° C. is necessary. Like colloids the alkali chars remain suspended in water and have a minus electric charge, but at p_H 3·8 flocculation and rapid settling takes place, the resulting material being electrically neutral and having the properties only of decolourising carbon.

Urbain[12] measured the adsorptive power of carbon, compressed to varying degrees, on different substances and attributed the variations to the different degrees of compactness, which was measured by the ratio of actual volume to apparent volume. With benzene the maximum adsorption occurred with a compactness of 0·3, chlorine increased regularly over a range of 0·19 to 0·59, whilst chloropicrin decreased regularly over the same range.

Paraffin Wax.—Waterman and Perquin[13] cracked paraffin wax at 450° C. in the presence of hydrogen according to the method Bergius, by which means they obtained liquid products that were more highly saturated than those produced by cracking without hydrogen. The formation of coke and gas was also less. After some hours berginisation a large percentage of gasoline and kerosene was obtained. The main feature of the reaction was not the saturation of unsaturated hydrocarbons but the prevention of disruption of saturated hydrocarbons. Shatwell[14] arrived at the same results independently.

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[9] *Rev. gèn. sci.* **36**, 229.
[10] G.P. 411,953.
[11] *Chem. Met. Eng.* **32**, 56.
[12] *Compt. rend.* **180**, 63.
[13] *Petr. Times* **13**, 259.
[14] *Chem. and Ind.* **44**, 471.

An attempt to explain the varying temperatures at which solutions of paraffin wax in petroleum solidify after subjection to thermal treatment has been made by Sakhanov and Vassiliev.[15] A study was first made of the solubility of wax in various solvents at different temperatures and the effect of these on the setting points of the solutions and the quantity of solid separating out. During solidification the solvent is considered to be adsorbed by the crystals of wax, the quantity being dependent on the size of the crystals, which again is dependent on the previous thermal treatment of the solution. Gurvich,[16] however, considers that this adsorption is improbable and that the whole of the known facts concerning the hardening of paraffin solutions can be explained by the conception of a fine paraffin network in the meshes of which the viscous solvent is trapped.

A step in the direction of ascertaining the chemical constitution of paraffin wax has been made by Marcusson[17] by oxidising in the presence of MnO^2 and fuller's earth. Ordinary distilled wax gives rise to normal aliphatic acids only and therefore contains only normal aliphatic hydrocarbons. On the other hand, ceresin and undistilled petroleum wax produce branched chain acids and therefore contain branched chain hydrocarbons.

The solubility of paraffin wax in all fractions of petroleum oil, benzol, alcohols and acetic acid have been determined by Sachanen[18] who found a marked increase in solubility, with rise in temperature in all cases. At their melting points the waxes dissolved in all proportions in the oil solvents, benzol and amyl alcohol, but at other temperatures their solubility increases with decrease in melting point and specific gravity.

The production of cancer by petroleum appears, from the work of Kennaway,[19] to be due to the presence of unsaturated hydrocarbons of some type, since he found that a petroleum that produced no tumours in mice after prolonged experiments became an active cancer producer after exposure to a temperature of 880° C. The same results were found with coal tar and other substances.

Bachmann and Brieger[20] found that the higher the lubricating power of an oil the greater was its heat of wetting against finely divided copper. This was well illustrated in the case of liquid medicinal paraffin, which is well known to be a poor lubricant, since it gave a figure of 3.85 cals. against 12.1 cals for castor oil.

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[15] *Neptjanoe slancevoe Chozjajstvo* **6**, 820; C.A. **19**, 1771.
[16] *Chem. Zentr.*, 1925, 596.
[17] *Chem. Zeit.* **49**, 166.
[18] *Petr. Z.* **21**, 735.
[19] *Brit. Med. J.*, 1925, II., 1.
[20] *Koll. Zeit.* **36**, 142.

The difference in behaviour as regards settling point of natural and artificial solutions of paraffin waxes has been studied by Rakusin.[21] With organic solvents waxes behave as gelatine does with water, one per cent. of wax in benzine forming a jelly at 5–7° C., whilst a crude oil with 6 per cent. of wax solidified at 8° C. This difference is probably due in part to the isomeric conditions of the wax.

Oxidation Products of Petroleum.—The oxidation of cracked oils to produce fatty acids, ketones and aldehydes and aromatic compounds has been the subject of several patents. Ellis[22] cracked kerosene and heated the cracked products to a temperature below redness with insufficient air to bring about complete oxidation for the production of fatty compounds, whilst to produce aromatic compounds as well he employed a cracking temperature of 800–900° C. and oxidised with moist air in the presence of a catalyst such as chromium or vanadium oxide at a temperature of 300–400° C. Weber[23] produced aromatic compounds, such as phthalic acid and anhydride, by oxidising the cracked gases in the presence of vanadium oxide at 400–425° C., whereby substantially only the aromatic compounds are affected.

Tyschinin and Butkow[24] examined the oxidisability of transformer oils and found that refining with oleum increased this property even more than did Florida earth, but that the addition of a trace of the original oil or of the kerosene distillate restores resistance to oxidation. The protective action of kerosene or original oil is probably due to the formation of compounds of the aromatic hydrocarbons with those substances which occasion the oxidation.

Chlorine Compounds of Petroleum.—Liquid chlorination products of about 1.36 sp. gr. and a boiling range of 55–193° C. are formed from cracked petroleum gases by Payne and Montgomery[25] by treating them with chlorine at 150° C. in the presence of a porous catalyst produced by the action of chlorine on an oil of high boiling point.

Ragaz, Paillard and Briner[26] cracked kerosene in the presence of iron turnings and mixed the gases at ordinary temperature with a slight excess of chlorine in diffused light. A better yield of chlorinated products was obtained in this way than when higher temperatures or ultra violet light were employed.

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[21] *Petroleum* **21**, 1498.
[22] U.S.P. 1,517,968.
[23] *Ibid.*, 1,516,756.
[24] *Chem. Zeit.* **96**, II., 253.
[25] U.S.P. 1,520,506.
[26] *Helvetica Chim. Acta* **8**, 225.

The toxic action of chlorohydrocarbons such as $C_2H_4Cl_2$ has been examined by Dougal,[27] who found that HCl was formed, with $COCl_2$ as an intermediate product, by oxidation in the body. This causes disintegration of the cell protoplasm, which accounts for the destructive action on parasites on animals, plants and in the soil.

[27] *Pharm. J.* **114**, 134.

Analysis and Testing of Petroleum.

By S. Bowman, F.I.C.

Notwithstanding the fact that most of the methods employed in the examination of petroleum and its products have now been standardised, a review of the literature for the past year shows that investigators are not content to accept these methods as final, but greater ease of manipulation and a higher degree of accuracy is constantly being sought for.

The American Society for Testing Materials[1] have, during the past year, issued several new tentative standards and revised existing methods and it is probable that the Institute will also revise their first edition[2] at an early date.

The difficult problem of ascertaining the composition of motor spirits has attracted the attention of a number of workers during the year, the importance of this subject being recognised by the Institution by providing facilities for a full discussion at one of their meetings.[3] Ormandy and Craven[4] tentatively suggested two methods for the determination of unsaturated hydrocarbons in petroleum spirit and gave the results they obtained with three or four different spirits. These workers showed that the aromatic content (C. S. T. method) deducted from the total loss in 98 per cent. sulphuric acid gave a result comparable to the loss in 80 per cent. acid plus the weight of gum formed. The unsaturated content as determined by the Hanus method, however, gave poor confirmation of these figures. Moore and Hobson[5] treated a cracked spirit with

[1] *Proc. Amer. Soc. Testing Materials*, 1925.
[2] Standard Methods, Inst. Petr. Techn.
[3] *Journ. Inst. Petr. Techn.*, 1926, **12**, 48.
[4] *Ibid.*, 1925, **11**, 533.
[5] *Ibid.*, 1925, **11**, 587.

an increasing strength of acid and noted the effect on the iodine value and aniline cloud point after each wash. From their results they concluded that 80 per cent. acid only partially removed the unsaturated hydrocarbons present and that it is necessary to use at least 90 per cent. acid for complete removal, under which conditions aromatics are probably also attacked. Using 80 per cent. acid Moore found that a rise of 1° C. in the aniline point corresponded to 2·6 per cent. of unsaturated hydrocarbons removed, but Brame[6] showed clearly from the results of his experiments that any polymerisation caused by the action of 80 per cent. acid would have a noticeable effect on the aniline point.

Houghton and Bowman[7], treating a cracked spirit with various strengths of acid, showed that the degree of polymerisation (ascertained by distilling up to the original F.B.P. and measuring the residue) reached a maximum with acid of 91 per cent. H_2SO_4. Although these researches are far from being conclusive, the data obtained cannot fail to be of value to future investigators.

Kattwinkel[8] determines the benzol content by extraction with sulphoacetic acid prepared by heating to 85° C. a mixture of 100 c.c. acetic anhydride with 8 c.c. of concentrated sulphuric acid. 10 c.c. of the spirit are shaken with 11 c.c. of the solvent and decrease in volume of the spirit noted. M. B. Cooke[9] determines the gumming constituents in gasoline by evaporation in an atmosphere of steam, so avoiding oxidation and loss due to creeping.

Several variations from the orthodox combustion method in ultimate analysis have been suggested. J. W. White and F. J. Holben[10] oxidise the material by boiling with a mixture of sulphuric and chromic acids in a Knorrs flask, followed by the usual absorption train. Vortmann[11] digests the material with a weighed amount of potassium iodate and sulphuric acid, the evolved gases being washed with potassium iodide, silver nitrate, and sulphuric acid solution respectively, before absorption in potash. The excess of iodate left in the flask is determined, thus giving the amount of oxygen required for the combustion and with the carbon dioxide obtained gives the necessary data for calculating the proportions of carbon, hydrogen and oxygen present.

Ter Meulen[12] has modified his hydrogenation method so that oxygen can be determined directly in the presence of nitrogen,

[6] *Journ. Inst. Petr. Techn.*, 1926, **12**, 48.
[7] *Ibid.*, 1925, **11**, 583.
[8] *Chem. Zeit.*, 1925, **49**, 57.
[9] *Petr. Times*, 1925, **13**, 973.
[10] *Ind. Eng. Chem.*, 1925, **17**, 83.
[11] *Z. anal. Chem.*, 1925, **66**, 272.
[12] *Rec. trav. chim.*, 1924, **43**, 899.

sulphur and halogens. A simple method for the determination of sulphur has been worked out by Heslinga[13] who burns the oil in a silica tube packed with pieces of quartz and heated to 900° C., in a stream of purified air. The oxides of sulphur are absorbed in hydrogen peroxide and titrated with standard alkali. Tintiunikov[14] heats the substance in a glass tube with powdered magnesium. The magnesium sulphide formed is then decomposed with sulphuric acid and the liberated hydrogen sulphide absorbed in caustic soda. A new rapid method for sulphur in kerosene has been worked out by E. S. Squire[15]. The oil is burned from a lamp in the usual manner and the gases are passed through a known quantity of $\frac{N}{160}$ sodium carbonate solution. This solution also contains potassium iodate and iodide and starch so that when the neutral point is reached the solution immediately turns blue. A slight error inherent in the method is corrected by means of a curve, and accurate results can be obtained in 15 to 45 min. by inexperienced operators.

A modification of the Ormandy method for estimating free elemental sulphur in spirit has been put forward by S. T. Card.[16] The mercury after agitation with the spirit is run through two layers of filter paper contained in a Gooch crucible. In this way the sulphide is collected in a comparatively clean condition and is dissolved by digesting the crucible in *aqua regia*. Excess of acid is neutralised and precipitation carried out in the usual manner.

Analysis of hydrocarbon gases always presents difficulties, especially when olefines are present. Tropsch and Dittrich[17] show that absorption of olefines in fuming sulphuric acid is unreliable owing to the action on certain paraffins. They find that concentrated acid to which has been added vanadic acid, uranyl sulphate or silver sulphate, effectively absorbs ethylene. A scheme is given for the complete analysis of a complex mixture of these gases. An apparatus[18] has been devised for determining the content of hydrogen sulphide in gas by means of a series of indicators of increasing sensitivity.

A useful gas absorption pipette is described by Jones[19] which is easily cleaned and can be used for successive reagents without contamination of the mercury.

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[13] *Chem. Weekblad.*, 1925, **22**, 98.
[14] *Chem. Zentr.*, 1924, **11**, 264.
[15] Paper read before Soc. Chem. Ind. (Swansea), Nov. 20, 1925.
[16] *Journ. Inst. Petr. Techn.*, 1925, **11**, 558.
[17] *Brennstoff-Chem.*, 1925, **6**, 169.
[18] E.P. 227,039, May 15, 1924.
[19] *J. Soc. Chem. Ind.*, 1925, **44**, 115T.

Borodulin[20] suggests a simple method for determining viscosity by timing the flow of drops of water from a glass jet through a depth of 10 cm. of oil. Barton and Browning[21] measure the viscosity of a liquid by the damping effect on a pendulum carrying a pair of planes immersed in the liquid under test.

As a means of determining viscosity at high temperatures,—*i.e.*, above the limits of the usual instruments, C. B. Bellis[22] employs an electrically driven paddle. The motor has previously been calibrated against liquids of known viscosity and the voltage required under standard conditions is a measure of the viscosity under test. S. T. Minchin[23] advocates the use of the Ostwald viscometer and conversion to Redwood units, on the grounds that less time is required and the temperature control more accurate.

The A.S.T.M. Pour Point test has been adversely criticised[24] by users in that country, especially when dealing with paraffin base oils. It appears that the behaviour of paraffin in solution under various temperature conditions is so obscure that the results obtained by this test are misleading and not reproducible.

L. D. Wyant and L. G. Marsh[25] have worked out a method for the estimation of wax in oil, using acetone as a precipitant. The advantage of the method lies in the fact that filtration can be carried out at 60° F. and the wax obtained is sufficiently pure to give a reasonable melting point. Von der Heyden and Typke[26] have studied the effect of variation in conditions of conducting the sludging test for transformer oils. Oxygen is considered to have the greatest influence, and the temperature of the test should be not above 120° C. as changes are likely to occur which are not reproduced in transformer practice.

W. M. Seaber[27] conducts the Conradson test for carbon residue in an electrically heated oven with good temperature control at 900° F. It is claimed that more concordant results are thus obtained.

A new electrometric method for the determination of acidity is proposed by Hech[28], based on the theory that when two similar metallic electrodes are immersed in solutions having a common ion in different proportions and connected by a non-metallic

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[20] *Petroleum*, 1925, **21**, 445.
[21] *Phil. Mag.*, 1924, **47**, 495.
[22] *Chem. and Met.*, 1925, **32**, 645.
[23] *Journ. Inst. Petr. Techn.*, 1925, **11**, 284.
[24] *Oil Trade Jour.*, 1925, **16**, 16.
[25] *Oil News*, 1925, **17**, 38.
[26] *Petroleum*, 1925, **22**, 1377.
[27] *Industrial Chemist*, 1925, **1**, 79.
[28] *Proc. Amer. Soc. Testing Materials*, 1925, **25**, 282.

conductor, an E.M.F. is set up which varies with the difference in concentration in the two solutions.

C. E. Wood and A. E. T. Neale[29] estimate the water content of an oil by distilling a solution of the oil in toluol or xylol and noting the amount of aniline required for critical solution of the distillate at 20° C. From a previously constructed curve prepared from known mixtures of the solvent with water, the actual water content is found.

Wilson and Allibone[30] discuss the methods for the evaluation of lubricating oils and interpretation of results. A similar contribution to this subject is also made by H. Moore.[31]

[29] *Journ. Inst. Petr. Techn.*, 1925, **11**, 471.
[30] *Ibid.*, 1925, **11**, 177.
[31] *Ibid.*, 1925, **11**, 571.

Oil and Gas Developments in Canada.*

By G. S. Hume, Geological Survey of Canada.

Alberta.—Two fields in Alberta produced oil in 1925. These are the Turner Valley field, about 35 miles south-west of Calgary, and the Wainwright field, 120 miles south-east of Edmonton. The Turner Valley field is within the Foothills area and is an anticlinal structure, described in this *Journal* in a previous report,[1] whereas the Wainwright field lies in eastern-central Alberta in the Plains area.

The Turner Valley field has produced a quantity of light oil for a number of years but no large production was obtained until Royalite No. 4 well was completed in the Autumn of 1924. This well, at a depth of 3740 ft., penetrated a productive horizon in strata generally considered to be carboniferous in age and "came in" with a flow of wet gas estimated at about 20,000,000 cub. ft. per day. On account of the heavy pressure that developed at the time the gas flow was struck the casing in the well was broken and the well cannot be completely closed in. The gas was piped from the well for about half a mile and after being passed through two Smith separators which extracted the naphtha, the gas was burned at the end of the pipe-line. During 1925 a scrubbing plant

* Published by permission of the Director, Geological Survey of Canada.
[1] *Journ. Inst. Petr. Techn.*, 1925, **11** (51), 411-417.

to extract the sulphur compounds from the gas was erected in the Turner Valley field and a 10-in. gas pipe-line constructed to Calgary. In November the scrubbing plant was ready for operation and the treated gas was turned into the Calgary pipe-line, thus eliminating the unavoidable waste of gas. Also, during 1925, a 4-in. oil pipe-line was constructed to Calgary and the naphtha recovered by the Smith separators is now being sent to the Imperial Oil Company's refinery in Calgary *via* the pipe-line whereas in the earlier part of the year the naphtha had to be transported by motor truck to Okotoks and there loaded in tank cars on the railroad.

The naphtha recovered from the wet gas from Royalite No. 4 well for 1925 amounted, according to the Dominion Bureau of Statistics, to 157,081 barrels valued at $703,030. Besides this a considerable revenue is now derived from the sale of gas for 10 cents. per 1000 cub. ft. after treatment in the scrubbing plant.

The phenomenal success of Royalite No. 4 well has brought about much drilling activity in the Turner Valley field, and many wells by various companies are now being drilled. None of these has as yet reached the pay horizon of Royalite No. 4 well. Besides the wells in the Turner Valley field a number of other wells have been located and are drilling on other possible structures in the Foothills area.

In Southern Alberta, the Rogers-Imperial well on section 29, tp. 1, r. 11, w. of 4th mer., which came in with a flow of 50,000,000 cub. ft. of gas[2] at a pressure of 1180 lb. per sq. in. in 1924 was deepened in 1925 and encountered additional gas but no commercial oil production.

The Imperial Dead Horse Coulee well No. 2 on section 32, tp. 1, r. 11, w. of 4th mer., on what is supposed to be the same structure as that on which the Rogers-Imperial well is located, got a good show of oil but no commercial production.

The Roth well at Medicine Hat being drilled under arrangement with the city of Medicine Hat got a gas flow of 2,600,000 cub. ft. of gas[3] at 1081 ft. in the Medicine Hat gas sand. Below this water was encountered at 2175 and 2525 ft. and at a still deeper depth a heavy gas flow was encountered. The gas flow, however, diminished very rapidly and probably is of little commercial importance. The well is being drilled still deeper.

In the Foremost field the Canadian Western Natural Gas, Light, Heat and Power Company drilled Nos. 5 and 6 wells. No. 5 well came in with a flow of 11,000,000 cub. ft. per day, and No. 6 with

[2] Charles C. Ross, "Petroleum and Natural Gas Development in Alberta," *Trans. Can. Inst. of Min. and Met.*, 1926, 19.
[3] *Ibid.*

a flow of 1,330,000 cub. ft. The depth to the gas sand in this area is about 2200 ft. Gas from the Foremost field is transported by pipe-line to Calgary.

In the Wainwright field in eastern-central Alberta, British Petroleums drilled No. 3 B well during 1925. At a depth between 2239 and 2259 an oil sand was found in strata of Lower Cretaceous age. The well is reported to have a pumping capacity of 50 to 75 barrels a day, but no official test has as yet been made. The oil from this well has a gravity of about 19° Baumé whereas the oil from No. 2 and 4 British Petroleum wells has a somewhat less gravity and is produced from sands in strata of Colorado age. The finding of the lighter gravity oil at depth has stimulated drilling activity in the Wainwright field, and a number of new wells will be drilled in 1926. The investigations of the Geological Survey have shown that there are a number of folds crossing Battle river in a north–west south–east direction, and it is on one of these, called the Wainwright–Battle River fold, that the Wainwright field is being developed. The Fabyan fold on which Maple Leaf No. 1 and Imperial (Fabyan) No. 1 gas wells have been drilled, is, it is thought, a separate fold somewhat further west down the regional dip.

Other than No. 3 B British Petroleums, no wells were completed in the Wainwright field during 1925 although it is reported the Western Consolidated and the Interior Oil Company's wells will be finished in 1926.

East of the Wainwright field in the vicinity of Battle river at the Alberta-Saskatchewan boundary the Geological Survey in 1925 outlined a possible new oil and gas structure known as the Ribstone-Blackfoot anticline. Preparations are under way for drilling on this structure in 1926.

In the Viking gas field which supplies Edmonton and adjoining towns, the Northwest Utilities, Ltd., drilled two new wells which came in with an open flow of 7,000,000 and 9,000,000 cub. ft. daily at a rock pressure of 710 lbs.

Fort Norman Area, N.W.T.—The Imperial No. 2 Discovery well drilled about 150 ft. from No. 1 well on the east bank of Mackenzie river, north of Fort Norman, was deepened to 1602 ft. during 1925. Oil was encountered at several horizons but particularly at 936 and 1063 ft. in the Fort Creek shale series of Upper Devonian age. The well has a capacity of about 110 barrels per day, the productive horizon being about the same as in No. 1 well, which gave 36° Baumé oil.

In the Fort Norman area to date the Northwest Company (Imperial Oil Company) have drilled four wells and abandoned one other on account of drilling troubles. Besides these, the Fort

Norman Oil Company drilled one well to a depth of about 1500 ft. Only two of these wells, Nos. 1 and 2 Northwest Company, have given an oil production. The structure of the Fort Norman oil area is a basin between the Norman range of mountains on the east and the Carcajou mountains on the west, and the two productive oil wells are on the eastern flank of the basin. There is some evidence of cross-folding in the basin, but of two known cross-folds both are eroded below the productive oil horizon of the wells. There is, however, a large part of the basin to the south of the present known cross-folds and this offers possibilities for other folds less deeply eroded, in which oil accumulations are possible.

It is reported that the Imperial Oil Company will not attempt further exploration in the Mackenzie region in 1926. According to the *Imperial Oil Review*, the small refining plant at the wells may be put into operation to refine the crude oil and supply local demands in the Fort Norman area.

Ontario.—Drilling in Ontario during 1925 was continued mostly by the gas companies and has met with some measure of success. The production of oil in Ontario during 1923 was, according to the Dominion Bureau of Statistics, 143,445 barrels, a decline of about 10,000 barrels from the previous year.

Maritime Provinces.—The Henry L. Doherty interests of New York have secured the rights to test Prince Edward Island and a well has been started on Governors Island in the harbour of Charlottetown. The Stony Creek field of New Brunswick has for many years produced oil and gas from the Albert Series of Mississippian age. The proximity of this field to Prince Edward Island has led to the hope that the same oil-bearing series will be found on Prince Edward Island under beds presumed to be of Permian age.

British West Indies.

By A. P. Catherall, B.Sc., M.I.Min.E., A.M.Inst.M.M.

Trinidad.

The period under review has been marked by steady progress in the development of the proven fields of the colony rather than by the development of new areas. The greater part of the output of crude oil has been won from the Fyzabad-Morne L'Enfer-La Brea districts from which an increasing production is being obtained. Towards the close of the year, however, preparations were in

progress for the inauguration of an active drilling programme in several new areas. If these efforts meet with success it is probable that a largely increased production will result in the near future.

The following table will show the number of feet drilled and the quantity of oil produced during 1925 compared with the years 1923 and 1924 :—

	Year ended December 31, 1923.		Year ended December 31, 1924.		Year ended December 31, 1925.	
	Feet drilled.	Oil won. Barrels of 35 galls.	Feet drilled.	Oil won. Barrels of 35 galls.	Feet drilled.	Oil won. Barrels of 35 galls.
Crown lands ..	87,148	1,910,547	97,039	2,486,269	105,631	2,877,437
Private lands ..	58,653	1,140,325	54,853	1,570,343	63,522	1,509,070
	145,801	3,050,872	151,892	4,056,612	169,153	4,386,507

The footage drilled and the production obtained over the period 1911–12 to 1925 will be seen from the accompanying graphs.

During the year under review 99 new wells were drilled, in 65 of which oil was struck. The total number of wells drilled in the colony to December 31, 1925, is 1027.

The exports of petroleum products show a large increase compared with last year, the figures being 126,000,000 galls. valued at £1,560,000 as against 113,000,000 valued at £1,367,000 during 1924. The major portion of the export trade is in the form of oil fuel of which a large part is shipped to the Admiralty under contract.

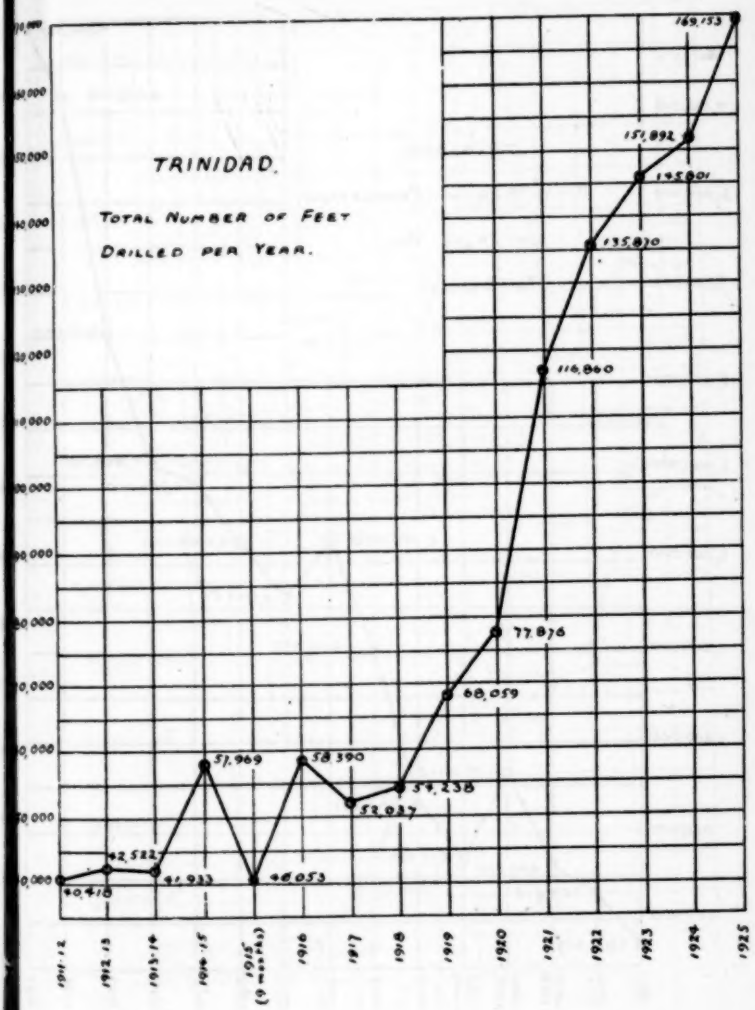
No new shipping or refining depots have been constructed during the past year, though some additions have been made to existing installations. The four terminal points for oil shipments are :—

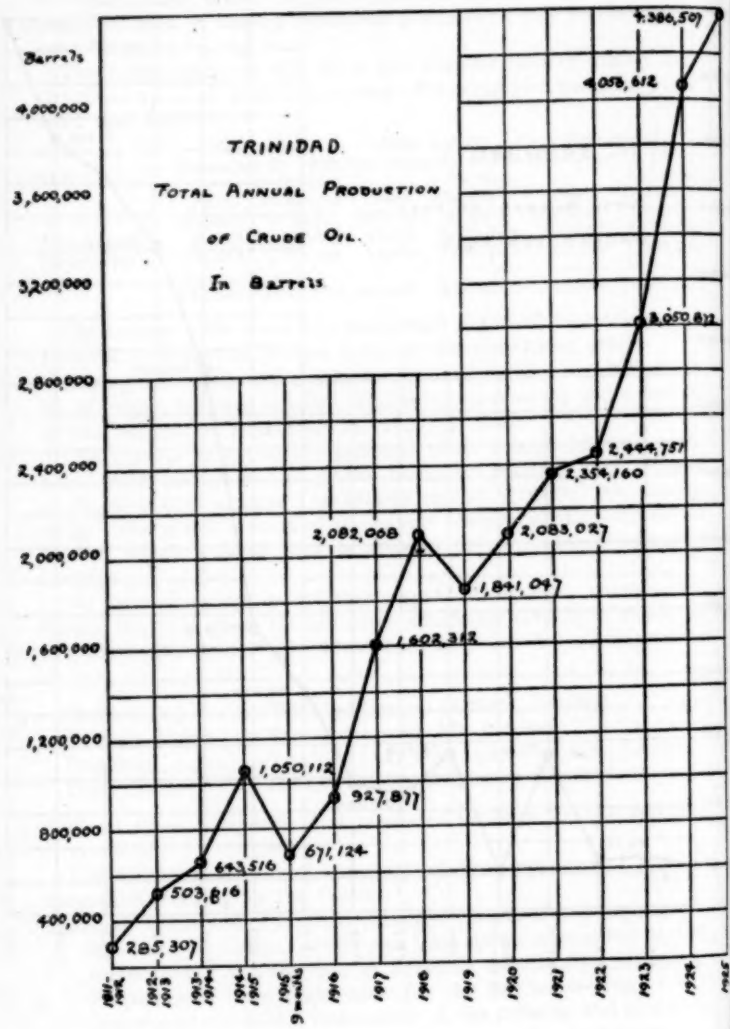
Claxton Bay	.. Trinidad Central Oilfields, Limited.
Pointe-a-Pierre	.. Trinidad Leaseholds, Limited.
Brighton ..	.. Trinidad Lake Petroleum Company, Limited.
Point Fortin	.. United British Refineries, Limited.

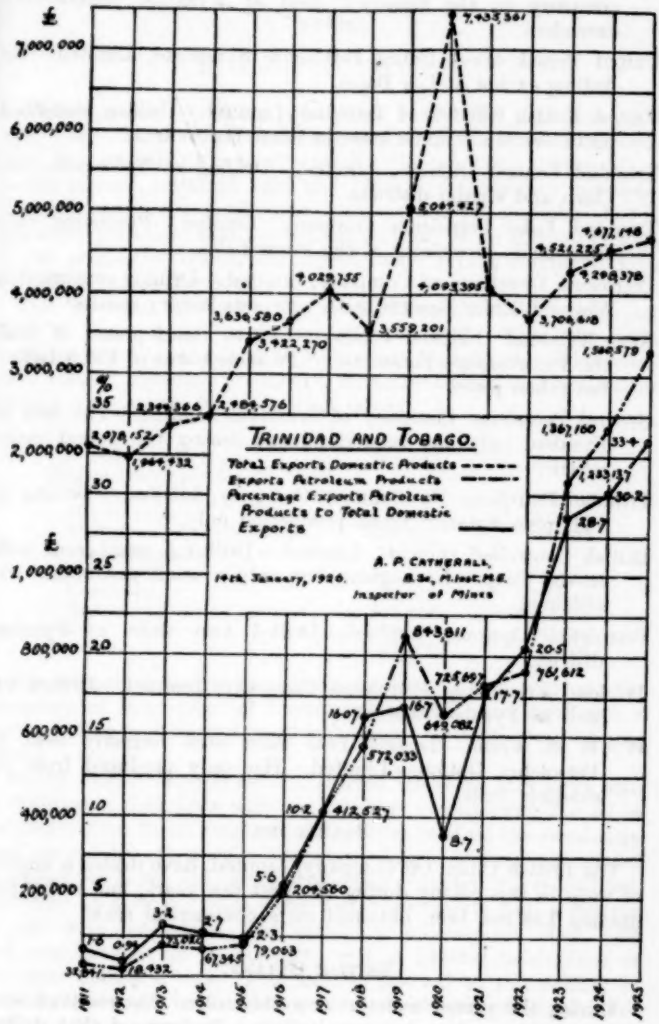
Each of these companies also possesses facilities for the refining of crude oil.

The following is a brief summary of the operation of the oil companies working in the Colony.

Trinidad Leaseholds, Limited.—Largest producing company in the Colony. Great activity has been shown during the period under review and the field at Fyzabad considerably extended. Preparations have been made for the further testing of the Guayaguayare field. Extensions of the refining and shipping depot at Pointe-a-Pierre are in the course of construction.


TRINIDAD.
TOTAL NUMBER OF FEET DRILLED PER YEAR.
40,418
42,522
41,933
51,969
46,053
58,390
52,027
54,238
68,059
77,876
116,860
135,830
151,892
169,153
1911-12
1912-13
1913-14
1914-15
1915 (9 months)
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925


TRINIDAD.
TOTAL ANNUAL PRODUCTION
OF CRUDE OIL.
IN BARRELS
Barrels
4,000,000
3,600,000
3,200,000
2,800,000
2,400,000
2,000,000
1,600,000
1,200,000
800,000
400,000
285,307
503,816
643,516
1,050,112
671,124
927,877
1,402,312
2,082,008
1,841,047
2,083,027
2,354,160
2,444,751
3,650,832
4,059,612
4,386,507
1911-1912
1912-1913
1913-1914
1914-1915
1915 9 months
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925


£
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
1,000,000
800,000
600,000
400,000
200,000
%
35
30
25
20
15
10
5
TRINIDAD AND TOBAGO.
Total Exports Domestic Products
Exports Petroleum Products
Percentage Exports Petroleum Products to Total Domestic Exports
A. P. CATHERALL, B.Sc., M.Inst.M.E. Inspector of Mines
19th January, 1926.
7,433,361
5,067,427
4,029,355
3,634,580
3,922,270
3,559,201
4,095,395
3,709,618
4,521,225
4,672,198
4,298,378
2,378,366
2,078,152
1,964,932
2,484,576
1,360,160
1,383,137
1,580,879
843,811
725,697
761,612
572,033
642,082
412,527
209,580
79,063
67,345
78,932
25,082
33·4
30·2
28·7
20·5
17·7
16·7
16·07
10·2
8·7
5·6
3·2
2·7
2·3
1·8
0·9
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925

Apex (Trinidad) Oilfields, Limited.—Second largest producing company in the Colony; field at Fyzabad considerably extended.

United British West Indies Petroleum Syndicate, Limited.—No drilling except at Los Bajos.

United British Oilfields of Trinidad, Limited.—Drilling continued on Crown lands under lease in Point Fortin area.

Trinidad Central Oilfields, Limited.—Drilling at Tabaquite, Rio Claro and Guapo districts.

Trinidad Lake Petroleum Company, Limited.—Producing only from lands in vicinity of the Pitch Lake.

Petroleum Development Company, Limited.—Drilling continued in Morne L'Enfer Reserve with very satisfactory results.

Kern Trinidad Oilfields, Limited.—Active development of both the Perseverance Estate and "Protected area of Pitch Lake" has taken place.

General Petroleum Company of Trinidad, Limited.—The field at Fyzabad only has been developed during the period under review.

Trinidad Petroleum Development Company, Limited.—Drilling on Phillipine Estate; small production only.

British Controlled Oilfields, Limited.—Drilled a number of wells in the Oropouche Lagoon, but only a small production was obtained.

Petroleum Options, Limited.—Drilled two wells in Fyzabad district.

Trinidad Friendship Petroleum Company, Limited.—Drilled one well in Fyzabad district.

W. B. S. Collie.—Leased Palo Seco area formerly held by Petroleum Options, Limited. Has only produced from the existing wells.

Barbadoes.

The British Union Oil Company, Limited, have drilled a number of wells in this colony during the past few years, but so far production has not been obtained on a commercial scale.

British Guiana.

During the period under review this colony has received some attention from oil prospectors and it is understood that drilling operations are expected to commence in the near future.

Japan.

By TOYOKICHI TAKAKUWA.

The Japanese petroleum production passed the peak ten years ago, when the total production was 3,008,500 barrels, and since 1917 the gradual drop in the production has been continued up to the present, although 1921 and 1924 gave temporary increases. The official returns of the year 1925 are not yet available, but it might be presumed that by estimation there is no marked change in the production during the period under review compared with 1,812,962 barrels for 1924.

The following table gives the crude oil production by principal fields of Japan and Fomosa for 1924 and 1925. From the table it will be seen that the fields of Nishiyama, Michikawa and Formosa have yielded increased production notwithstanding that the others showed a reduction from the 1924 output.

District and Field.	1924. Barrels.	1925. Barrels.
Niigata Prefecture—		
Niitsu and Omo	520,946 ..	493,903
Higashiyama	106,361 ..	102,898
Nishiyama and Nanukaichi..	202,049 ..	296,329
Akita Prefecture—		
Toyokawa	296,129 ..	279,025
Kurokawa	222,448 ..	210,045
Michikawa	200,834 ..	214,382
Yuri	125,656 ..	122,724
Formosa	22,473 ..	26,101

The important points of interest to note in this year are the discovery of new deep oil formation in Nishiyama field and a feature giving prospects of possible increased production of Formosa oilfield.

No. 38 well of Nippon Oil Co. started the work at Takiya area of Nishiyama field 1924 with an intention of obtaining the oil in the 3000—3300 ft. oil sand in which existence of oil has previously been proved by other wells, but even though drilling was carried to 3600 ft. no indication of the production expected was recognised. However, at 4198 ft., when hope was beginning to fail, a flowing of oil with abundant gas suddenly commenced and this well was brought in in January, with a natural production of 170—280 barrels a day. This success has led to the drilling of several other wells in that area, all of which proved highly productive. Many productive underlying formations in Nishiyama field have already been pumped, but the sand above mentioned

was the deepest one ever reached in Japan, and it added confirmation to the proofs of the deep formation of the field. Prior to the success of No. 38 well, the Nippon Oil Co. decided on a plan of deeper drilling to not less than 6000 ft. in Kamada, a sub-division of the Nishiyama field, and started the drilling in June with a special drilling equipment introduced from California, having reached 4264 ft. at the close of the year.

According to analysis made by Mr. M. Mizuta, of the Nippon Oil Co., the crude oil coming from No. 38 well is greenish red in colour of paraffin base and has the following properties: Specific gravity, 0·804; paraffin scale, 1·5 per cent.; sulphur, 0·17 per cent. By fractional distillation it yields as follows: Light oil of sp. gr. 0·735, 40 per cent. by volume; kerosene of sp. gr. 0·814, 20 per cent.; gas oil of sp. gr. 0·892, 27 per cent.; residual oil of sp. gr. 0·935, 12 per cent.

No. 2 well of Nippon Oil Co. at Takamachi, southern extremity of Nishiyama field, also came in as a gas well in April, with an open flow not less than 20,000,000 cu. ft. per day, and it is recorded as the largest gas well ever performed in Japan proper. The gas is being used for making casing-head gasoline, and also is supplying fuel to the Nishiyama field and Kashiwazaki refinery, which is a few miles south-west of the field.

Such conditions above mentioned are very encouraging for development of Nishiyama oilfield, which has continued a sharp decline during the last few years, and there is some reason to hope that production might be to some extent increased in the near future. But still, the prospects for developments leading to a large increase in production, and the financial considerations of whether the results are likely to justify the expenditure, are a matter of question.

The oilfield of Formosa, which has been displaying again a slight progress since 1922, has shown new possibilities for more development this year, and more activity of oil industry is anticipated in the coming year. Toward the end of 1925, No. 36 well of the Nippon Oil Co. in the Shiyukkokko area of the Biorytsu field came in as a gusher at the depth of 2200 ft., and a daily production of around 226 barrels was reported. It was the largest productive oil well ever drilled in Formosa, and the drilling of several other wells, the extension of the Biorytsu refinery, and the installation of tank storage are being prepared by the company.

In the Zokio area of Biorytsu field several oil wells have been drilled since 1911, but they have not yet proved an oilfield, although possibilities of a large gas field are shown. Gas under enormous pressure was struck by No. 1 well of Hoden Oil Co. at 852 ft. in December, 1914, which was recorded as the largest

gas well in Japan and Formosa. Many attempts were then made to shut in the well, but all failed, and the flow of gas, without being under control, continued for six months. No. 5 well in the same area was commenced in May, 1923, and a flow of gas was encountered at 1812 ft. and 2160 ft. respectively, but these gases were all of dry quality.

At 2700 ft. a very strong flow of gas was struck in October, 1924, and it was a larger flow than either of the two previous flows of this well, being estimated at 10 to 20 million cu. ft. per day. The gas was of a wet quality, containing much gasoline constituents. A gasoline plant on the absorption system was completed toward the end of the year and about 50 barrels of gasoline are now being produced, using a part of the gas, since the beginning of 1926. From the volume and character of the gas, as well as the geological point of view, it would appear that a large reservoir of oil and gas exists in the further deep formation, and no doubt more deep drilling will be undertaken.

No new refining installation has been constructed during the past year, though some additions to existing installation have been made.

The Production of Oil-Shale and Shale-Oil in Estonia.

By P. N. KOGERMAN, M.Sc., D.I.C., F.C.S.

The production of oil-shale has steadily increased since the beginning of the Oil-Shale Industry in Estonia. In 1925, five mines were marketing oil-shale, two belonging to the "State Oil-Shale Industry" and three to private companies. Since 1918 the production of oil-shale, in tons, has been :—

PRODUCTION OF OIL-SHALE IN METRIC TONS.

Year.	State Oil-Shale Industry. Kohtla Mine.	State Oil-Shale Industry. Kukruse Mine.	Vanamoisa Mine (E.O.D.S. Ltd.).	A/s "Eesti Kivioli."	A/s "Kutte Joud."	Total.
1918-1919	9,648	—	—	—	—	9,648
1921 ..	84,511	3,740	7,276	—	—	95,527
1923 ..	177,000	29,000	3,340	6,600	—	215,940
1925 ..	235,000		8,600	15,390	24,700	283,690

The greater portion of the oil-shale produced in 1925 was used as fuel for direct combustion, and only 22,395 tons, or

about 8 per cent., was used for the production of shale-oil, as follows :—

PRODUCTION OF SHALE-OIL.

	Amount of oil-shale distilled. Metric tons.	Products obtained. Crude oil. Gall.	Benzine. Gall.
"State Oil-Shale Industry" at Kohtla	18,459	587,380	2,770
The Estonian Oil Development Syndicate at Vanamoisa	3,936	100,000	6,556

Properties of crude oils and their products :—

KOHTLA SHALE-OIL.

System of Retorting.—Vertical, internal heated retorts of the producer type, designed and erected by Messrs. J. Pintsch & Co., Ltd., Berlin, are used. The throughput of the plant is 200 tons of oil-shale per 24 hours, but during 1925 only three of the six retorts were in operation.

Properties of Crude Oil.—An analysis of the crude shale-oil, carried out in the Kohtla laboratories, gave the following :—

Sp. gr. at 15° C.	0·98 to 1·01.
Reaction	Neutral.
Moisture	About 1·0 per cent.
Flash point (Pensky Martens)	Over 80° C.
Viscosity at 50°	3·5 to 4·5° E.
Cold test	—10° C.
Unsaturateds	75 to 90 per cent.
Insoluble in normal benzine	1 to 2 per cent.
Coke test (in crucible)	9 to 11 per cent.
Sulphur	Below 1 per cent.
Mechanical impurities	0·05 per cent.
Calorific value	9800 cals./kg.
Distillation test :	
Up to 200° C.	3—5 per cent.
200 to 250° C.	10—12 per cent.
250 to 300° C.	10—12 per cent.
300 to 360° C.	30 per cent.

Diesel Oil.—The properties of this product are :—

Flash point (Pensky Martens)	Over 60° C.
Viscosity at 50°	1 to 1·3° E.
Unsaturateds	40 to 50 per cent.
Insoluble in benzine	About 1 per cent.
Coke (in crucible)	3 to 4 per cent.
Sulphur	0·5 to 0·9 per cent.
Mineral matter	Under 0·05 per cent.
Moisture	About 1 per cent.
Calorific value	10,000 cals./kg.
Distillation test :	
Up to 200° C.	5—8 per cent.
200 to 250° C.	15—20 per cent.
250 to 300° C.	20—30 per cent.
300 to 360° C.	30—40 per cent.

Pitch.—The distillation residue of the crude oil has a melting-point of 70–90° C., and is suitable for use in the manufacture of roofing paper and as an insulation material.

Goudron and Asphalt.—The shale asphalt is of good quality and is used as a substitute for natural asphalts.

Vanamoisa Shale-Oil.

System of Retorting.—Horizontal, external heated "Fusion" retorts are used, the retorts being manufactured by Messrs. Vickers, Ltd., and the oil condensers and benzol recovery plant by Messrs. Meldrums, Ltd., Manchester. The throughput of a single unit, two of which have been installed, is 24 tons of dry shale per 24 hours, the yield of oil being 50 to 60 gall. per ton of dry shale.

Crude Oil.—An analysis of the crude, made by the author, is as follows :—

Sp. gr. at 15° C.	0·950 to 0·969.
Viscosity at 50° C.	1·6° E.
Moisture	1·1 per cent.
Dust and free carbon	0·54 per cent.
Unsaturateds	About 27 per cent.

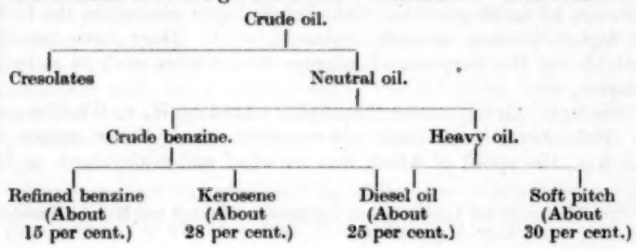
(*Note.*—1 vol. oil + 1 vol. benzine + 4 vols. H_2SO_4 80%).

Distillation test (Engler) :

Amount of oil taken	92·2 g.
I.B.P.	70° C.
Up to 150° C.	7·7 c.c.
150 to 175° C.	5·9 c.c.
175 to 200° C.	4·6 c.c.
200 to 225° C.	6·0 c.c.
225 to 250° C.	5·9 c.c.
250 to 275° C.	6·9 c.c.
275 to 300° C.	6·4 c.c.

Although the refinery is not yet fully equipped for the production of all the possible products from the crude oil, steps are being taken to instal the necessary plant as soon as possible. During the last year some refined products were produced at the chemical works of Messrs. Richard Mayer & Co., Ltd., Tallinn, Reval, and these have proved highly satisfactory.

The scheme of refining Vanamoisa "Medium Oil" is as follows :—



Benzine.—A very high quality of aviation spirit and motor spirit is obtained :—

Aviation Spirit.		Motor Spirit.	
I.B.P.	45° C.	I.B.P.	58° C.
50 per cent at ..	100° C.	28 per cent. at ..	100° C.
94 per cent. at ..	150° C.	87 per cent. at ..	150° C.
End point	165° C.	97 per cent. at ..	170° C.
		End point	178° C.

Colour : Water white.

Kerosene.—The kerosene burns in an ordinary lamp with a somewhat smoky flame, owing to the high content of unsaturateds and the fairly high sulphur content, 0·68–0·77 per cent. The specific gravity at 15° C. is 0·813–0·850.

Diesel Oil.—This has been used in Diesel engines with good results, the properties being :—

Sp. gr. at 15° C.	0·899
Calorific value	10,200 cals./kg.
Viscosity at 20° C.	1·2° E.
Flash point	55 to 60° C.
Coke test	0·5 per cent.
Asphalt (with benzine)	Traces.
Sulphur	0·62 per cent.
Distillation test :	
Up to 200° C.	5·0 per cent.
200 to 250° C.	39·0 per cent.
250 to 300° C.	36·0 per cent.
300 to 350° C.	15·0 per cent.

Lubricating Oils.—From the heavy oil, cheap lubricating oils have been produced, the yield being 20–30 per cent., the analysis of a sample supplied by the producers being :—

Sp. gr.	1·011
Viscosity at 50° C.	8·3° E.
Flash point	152° C.
Asphalt	Traces.

Phenol Content.—The phenol content of Vanamoisa oil ranges between 15 to 20 per cent., the phenols being present in the form of higher phenols (cresols, xylenols, etc.). They have proved suitable for the purposes of impregnating timber such as railway sleepers, etc.

The light oils have been thoroughly tested by H. v. Winkler and L. Rubenberg,[1] who used a two-stroke two-cylinder motor of 3.5 h.p., the speed of which was recorded and maintained, as far

[1] Zur Kenntnis der Leichtole aus Kuckersit, Beitrage zur Kunde Estlands, Bd. XI., 1925, Heft. 3, pp. 83-96.

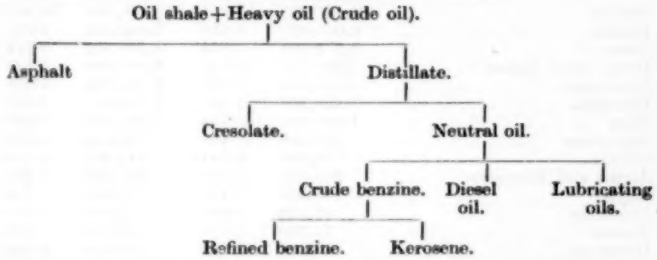
as possible, at 1500 r.p.m. Ten c.c. of the oils were tested, with the following results :—

Oil.	Time lasted. secs.
Normal benzine	20·27
Kukersite benzine	15·97
Kukersite light oil	17·02
Kukersite benzol	20·59

In all cases the exhaust gases were colourless and odourless.

The shale asphalt has been tested at the Material Testing Station in Tallinn by O. Maddison and F. Dreyer,[2] with satisfactory results.

A process has been patented by Messrs. E. Trampedach and R. Mayer, Ltd., Tallinn, Reval, for the direct production of asphalt from the oil-shale. The scheme is given below :—



Hydrogenation tests on both oil-shale and crude shale-oil are being carried out at the Oil-Shale Research Laboratory, University of Tartu, and the results will be published in due course.

World's Production of Crude Petroleum.

By George Sell.

The preliminary figures for the world's production of crude petroleum, exclusive of shale-oil, during the year 1925 show an increase of about 9 million metric tons, or nearly 7 per cent., as compared with the previous year. The following table, which is based as far as possible on official returns, gives the estimated production of crude petroleum by countries, together with the

[2] Ergebnisse der Festigkeitsprufung einiger aus Kukersit hergestellter Asfalte I. Riiklise Katsekoja Teated, No. 1, 1925. (Reports of the Material Testing Station at Technical High School, Tallinn.)

percentage production of each, the figures for 1924 being included for comparison :—

	1924. Quantity. Metric Tons.	1924. Percentage of Total.	1925. Quantity. Metric Tons.	1925. Percentage of Total.
United States :				
Appalachian	3,607,500	—	3,636,000	—
Lima-Indiana	304,900	—	282,800	—
Illinois and S.W. Indiana ..	1,166,300	—	1,133,700	—
Mid-Continent	50,063,900	—	56,128,800	—
Gulf Coast	3,809,200	—	4,194,400	—
Rocky Mountain	5,714,100	—	4,718,100	—
California	30,524,400	—	30,686,400	—
Other Fields	1,700	—	—	—
	95,192,000	71·810	100,780,200	71·143
Mexico	15,837,200	11·947	15,310,300	10·808
Russia	6,000,000	4·526	7,000,000	4·941
Persia	4,313,000	3·254	4,700,000	3·318
Dutch East Indies	2,825,000	2·131	3,000,000	2·118
Venezuela	1,257,000	0·948	2,722,000	1·921
Rumania	1,851,200	1·396	2,313,000	1·633
Peru	1,000,000	0·754	1,200,000	0·847
Argentina	610,000	0·460	830,000	0·586
Galicia	770,800	0·581	811,900	0·573
Japan and Formosa ..	260,000	0·196	280,000	0·198
Egypt	162,800	0·123	178,600	0·126
Colombia	65,000	0·049	135,000	0·096
France	74,300	0·056	65,000	0·046
Germany	50,000	0·038	55,000	0·039
Ecuador	9,000	0·007	18,000	0·013
Czecho-Slovakia	13,000	0·010	8,000	0·005
Italy	4,400	0·003	4,500	0·003
British Empire :				
India	1,100,000	0·830	1,025,000	0·723
Sarawak	600,000	0·453	613,000	0·433
Trinidad	541,000	0·408	585,000	0·413
Canada	23,500	0·018	22,000	0·015
Other countries	2,500	0·002	2,500	0·002
Total ..	132,561,700	100·000	141,659,000	100·000

The production of crude petroleum in the United States in 1925 increased by about 5½ million metric tons over that in 1924, although the percentage of the total production remained practically the same. The production by fields shows little difference from the 1924 figures, except in the Mid-Continent field, where the output increased considerably, and in the Rocky Mountain area, where the total production was less by about 1 million metric tons.

As regards other countries producing oil, with only few exceptions these showed an increase of production over the previous year, the most noteworthy being Venezuela, in which country the

quantity of crude petroleum produced was more than double that for 1924.

The quantity of crude oil obtained in the British Empire did not alter materially, the total for 1925 being 2,245,000 metric tons as compared with 2,264,500 metric tons in 1924, the percentage of the total world's production being 1·58 and 1·7 respectively. Canada and India are estimated to have produced slightly less than in the previous year, while Trinidad and Sarawak are credited with a small increase.